PAPERS AND PROCEEDINGS OF

The Royal Society of Tasmania

Edited by M. R. Banks and S. J. Smith
and Published by the Society
Hobart, Tasmania
October 1990

Volume 124, Part 1

MUSEUM OF VICTORIA
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Volume 124, Part 1

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His Excellency the Governor of Tasmania
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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA
Volume 124, Part 1

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ROYAL SOCIETY OF TASMANIA
ANNUAL REPORT FOR THE YEAR 1989

The Council has the honour to present to members the following report on the activities of the Society during the year.

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Honorary Assistant Editor
Dr S.J. Smith

President

His Excellency General Sir Phillip Bennett took the chair as President of the Society, at the Annual General Meeting and at the Annual General Meeting of the Northern Branch. He also took the chair at the September General Meeting in Hobart and attended the June meeting of the Northern Branch at the Northern Regional Library. The publication on the Tasman Peninsula Symposium was launched by His Excellency on 27 July.

Clive Lord Memorial Medal

At the General Meeting in September, the President presented the Clive Lord Memorial Medal to Dr Lloyd Robson in recognition of his contribution to Tasmanian history.

The award was established in 1934 to honour the memory of Clive Lord (1889–1933) and previous recipients have been:

1936	L.F. Giblin
1939	J.B. Cleland
1947	H. Thompson
1951	J. Burke
1958	P.G. Law
1960	V.V. Hickman
1966	W.M. Curtis
1973	W. Bryden
1977	E.R. Guiler
1983	N.J.B. Plomley
1986	R.G.H. Green

Annual Meeting

At the Annual Meeting on 7 March, Mr C.A.H. Payne retired as Vice-President and Dr J.S. Rogers and Mr R.R. Shepherd as Members of the Council. The following were elected:

Vice-President	Dr J.S. Rogers
Members of Council	Dr P.G. Quilty
	Dr V. Von Witt
Honorary Secretary	Mr D.R. Gregg
Honorary Treasurer	Mr T.A.H. Knight
Honorary Auditor	Mr R.J. Dwyer

Membership

The membership is 481, an increase of 32, and is made up as follows:

	Northern Branch	Total
Honorary Life Members	2	7
Life Members	12	38
Ordinary Members receiving *Papers and Proceedings*	72	305
Ordinary Members not receiving *Papers and Proceedings*	52	106
Associate Members	16	25
	154	481

Council Meetings

The Council met four times during the year.

Library

The Library was under the direction of Mrs Mary-Anne Secker until her resignation on 1 September, Mrs Gaye Thavisin then returned as librarian on a fractional basis from 4 September until 8 December when she too resigned. Mrs Thavisin was ably assisted by part-time clerical assistant Ms Julie Cariaga. New staffing arrangements are now in place for 1990.

During the year 393 visitors to the library signed the register, 126 journals were recorded as being consulted in the Library, and there were 151 loans from the serials section. The Library supplied 58 photocopied items in response to interlibrary loan requests. Binding of Royal Society Serials amounted to 188 volumes in 1989. This year, statistics of reference queries have been maintained for the first time — the librarian answered 147 short queries and 30 major enquiries from users.

As usual, the index for the 1988 volumes of the *Papers and Proceedings* was prepared and copies despatched to selected Tasmanian libraries. In December volume 123, 1989, was despatched to 292 exchange partners, 57 in Australia and the remainder overseas. During 1989, 7 new serial titles have been received (3 as a result of new exchanges initiated), and 8 titles have been cancelled, all as a result of exchange partners financially balancing exchanged publications and reducing the number of titles sent.

Special projects during the year included the installation of additional shelving to expand the crowded serial collection to accommodate five years growth; cataloguing of donated monographs (usually received from exchange partners) was initiated and the use of a new National Library on-line service was recommended The compilation of a consolidated index to volumes 89–125 (1955-91) will commence in 1990.

Publications

Two volumes were published by the Society in 1989. The first of these, edited by Dr S.J. Smith, was the *Tasman Peninsula. Is history enough? Past, present and future use of the resources of the Tasman Peninsula*. This volume, a collection of papers presented at the Society Symposium in November 1986, was dedicated to the memory of Sir James Plimsoll (1917–87) and included a foreword by the President, His Excellency General Sir Phillip Bennett, AC, KBE, DSO. Eighteen papers, involving 25 authors, were included in the volume, published in July and launched by the President at the Tasmanian Museum and Art Gallery on 27 July. The volume, with its index, occupied 156 pages.

The second publication was Volume 123 of the *Papers and Proceedings*, published on 21 November 1989, and edited by the Honorary Editor and the Honorary Assistant Editor. Volume 123 contained the Annual Report for 1988, together with 22 papers involving 39 authors and totalling 299 pages. Papers included the Banks Memorial Lecture by Sir David Smith, papers on industrial archaeology, botany, zoology, ecology, geology, palaeontology, history, oceanography, fisheries and parasitology.

Mrs Alison Jones sub-edited both volumes and Mrs June Pongratz prepared them for publication.

The Society is once more indebted to Dr Banks and Dr Smith for their dedicated editorial work.

Lectures

The following interesting and varied lectures were given at General Meetings during the year:

March — "Implications and changes in Australian Universities: challenges for higher education in Tasmania in the 1990's" Prof. Alec Lazenby, Vice-Chancellor, University of Tasmania

April — "The human exploitation ofshort-tailed shearwaters" Mr I.J. Skira, Dept of Lands, Parks and Wildlife

May — "The Menzies Centre for Population Health Research" Prof. T. Dwyer, University of Tasmania

June — "Marine micro-algae: from ocean pasture to mariculture" Dr Shirley Jeffrey, Division of Fisheries Research, CSIRO

July — "Science and technology — our future" Mr J.C.S. Bowler, Department of Science and Technology

August — "Psychology and economics" Dr Peter Earl, University of Tasmania

September — Clive Lord Memorial Lecture: "Tasmania and the imperial connection: outpost of Empire" Dr Lloyd Robson, University of Melbourne

October — "Aphids, plants and other organisms" Dr Victor Eastop, formerly of the British Museum (Natural History) and President of the Royal Entomological Society

November — "The development and export marketing of leading edge technologies from Tasmania's Technopark" Mr J.R. Gumley, Critec Corporation Pty Ltd

December — "Charles Darwin in Australia" (joint meeting with Tasmanian Historical Research Association, held at CSIRO Laboratories) Dr F.W. Nicholas, University of Sydney

Northern Branch

Chairman	Mr A.T. Orr
Vice-Chairman	Dr E.V.R. Ratcliff
Honorary Secretary	Mr C.B. Tassell
Honorary Treasurer	Mr B.A. Pike
Council Members	Dr D. McWilliam
	Mrs M.P. Little
	Dr D. Churton
Branch representatives on Council of Society	Mr A.T. Orr
	Mr C.B. Tassell

The Branch Council met four times during the year.

The following lectures were given at General Meetings:

March — "His natural life — 1926/1927" Prof. O.M. Roe, University of Tasmania

April — "On aspects of forestry" Mr I. Whyte, Forest Products Division, APPM

May — "Pain" Dr C.G. Merridew, Launceston General Hospital

June — "Northern Regional Library, Local History Room" Mr D.W. Dunstan, State Library of Tasmania

July — "Heritage in Antarctica" Ms E. Wishart and Mrs L. Clark, Queen Victoria Museum

August — "The University of Tasmania after 100 years" Prof. Alec Lazenby, Vice-Chancellor, University of Tasmania

September — "Tasmania and and imperial connection: outpost of empire" Dr Lloyd Robson, University of Melbourne

October — Excursion and discussion of the Aquacentre, Tasmanian State Institute of Technology

November — "The history of the streets of Launceston" Dr J.C.A. Morris

December — Members' Night
"Great Exhibitions 1851" Dr E.V.R. Ratcliff
"An oration of an unusual hero" Mr J. Kolkert
"Highlights of a medical career" Dr D. Churton

Excursions and special events:

2 June — Joint meeting with the Launceston Historical Society at the Northern Regional Library.

6 October — Visit to the Aquacentre, Tasmanian State Institute of Technology and general meeting.

Nominees to Other Bodies

The Council re-elected Mr A.R. Neilson and Dr P.G. Quilty to serve a further term on the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

The Tasmanian Museum and Art Gallery continues to collect and safeguard the physical evidence of the natural and human heritage of Tasmania, together with relevant material from beyond the state and beyond Australia. Objects in the collections are preserved and studied, and are exhibited for the education and enjoyment of the public.

The 1989 State budget provided $1 463 000 to the Tasmanian Museum and Art Gallery, an increase of 5.7% over the allocation in the 1988 Budget. Of this, 81% will be spent on salaries and related costs, about the same as in 1988–89.

The Taxation Incentives for the Arts Scheme, established by the Commonwealth Government in 1978, continued to give welcome encouragement to donors. In the 1988–89 financial year there were 11 donations under the scheme with a value exceeding $85 000. Donations under the scheme since 1978 have had a value at the time of donation exceeding $700 000.

The Art Foundation of Tasmania, established in 1984, continued to encourage support from the private sector for the Museum and Art Gallery. During the year 38 items, valued at over $173 000 were purchased for the collections with funds provided by the Foundation.

The Friends of the Tasmanian Museum and Art Gallery involved the community in the activities of the Museum and Art Gallery and provided $4 487 for the purchase of Tasmanian furniture and Tasmanian medallions and tokens.

Mr Hendrik Kolenberg, Curator of Art since 1980, who resigned as from the end of 1988 to take up a new position at the Art Gallery of New South Wales, was replaced by Dr Christa Johannes.

During 1989, 101 168 people visited the Museum and Art Gallery, compared with 134 661 in 1988. During the second half of the year visitor numbers were lower than usual, due to the air pilots' dispute.

The number of visitors to the West Coast Pioneers' Memorial Museum at Zeehan was estimated at 110 000.

The Bicentennial year continued well into 1989 with the showing of *The Great Australian Art Exhibition, 1788–1988* (December 1988-February), seen by 13 500 people, and *First Impressions, The British Discovery of Australia* (April-June), seen by 7000 people.

Other exhibitions shown included: *The Changing Silhouette, Fashion 1888 to 1988* (October 1988–February), *What's New? Gifts to the history collections 1984–88* (April–November), *British watercolours from the collection* (July–August), *Oliffe Richmond drawings, the Australian years* (August–October), *Send me more paint! Australian art during the second world war* (October–November), *Moët and Chandon Australian Art Foundation* (November–January 1990) and *Vincent McGrath, Timeprints* (December–January 1990).

A new gallery *Convicts in Van Diemen's Land* was opened in October.

Temporary displays have covered a wide range from world shells to Tasmanian silver.

During the year 13 983 students in school groups visited the Museum and Art Gallery. The Musbus travelling museum project continued to take museum displays to country schools in the south of the state. During 1989, 18 schools were visited and displays were shown at the Primary Schools Science Fair at Campbell Street School.

All departments of the Museum and Art Gallery are involved in research during preparation of displays and exhibitions, answering inquiries from the public, curation and documentation of the collection and the preparation of talks and articles.

The West Coast Pioneers' Memorial Museum at Zeehan, which is under the control of the Trustees of the Tasmanian Museum, is managed by a committee under the chairmanship of Mr R.G. Smith, OAM. During the year the committee, with the support of the Trustees, has put great enthusiasm and expertise into a proposal for the development of the West Coast Pioneers' Memorial Museum. This includes the establishment of an underground mine with displays for visitors illustrating the history of mining techniques on the West Coast as well as a working electric railway and aerial ropeway.

Dr J.E.S. Townrow was re-elected by the Council to a further term on the Board of Trustees of the Royal Tasmanian Botanical Gardens, but retired from the Board in December after having served since 1978. She has been replaced by Dr A.E. Orchard. Dr Townrow reports on the year's activities:

Nineteen-eighty-nine has been a year full of interest and expansion in several facets of the Garden's activities.

Visitors numbered about 274 000, up 4% on last year's total, the best patronage since 1987 when the Japanese Garden was first a major attraction.

The Board of Trustees commissioned a review of management operations and staffing of the gardens in collaboration with the Business Management Division of the Department of Public Administration (DPA) in April.

This action was taken to meet the challenge of mounting pressure placed on the Gardens staff through shortage of labour personnel and further cuts in finance and the need to provide the highest level of service to the public. All staff were given the opportunity to contribute to the review made by an independent consultant from the DPA, Mr Charles Cook. The review, which identified several areas for improvement, was timely in view of the new Government's restructuring of the State Service. This resulted in the Royal Tasmanian Botanical Gardens losing its independent status to become part of the new Department of Parks, Wildlife and Heritage, answerable to the Minister through the Department Secretary, Mr A.J. Pedder. The restructuring was designed to bring about efficiency gains and improved management practices maximising specialist skills available in both the Department and the Gardens. In practice the Gardens will, for all intents and purposes, continue unaffected although there will be changes in prescriptive terms of managing and superintendence and in arrangements under which the four Trustees are appointed by the Governor and their terms of office are carried out. One of these four will be nominated by the Secretary of the Department as Chairman instead of by election by the board members. As at this

time (January 1990) the legal implications are not completely clear and we await revised legislation.

The majority of Trustees from 1988 continued on the Board under the Chairmanship of Mr J.G.B. Hulton except that Dr R. Crowden, nominated by the University of Tasmania, succeeded Professor W.D. Jackson upon his retirement at the end of 1987. Alderman D. Plaister replaced Alderman G.A. Yeoland who retired due to ill-health in October and Dr Townrow (Royal Society nominee) retired in December after 11 years service to be succeeded by Dr A.E. Orchard.

Mr Andrew Smith, Information and Education Officer, has encouraged staff development and further training through attendance in part-time courses. Two of the staff have completed apprenticeships in stone masonry at Melbourne Technical College, one has completed the third year of an apprenticeship at Burnie Technical College, and four have completed the St Johns Ambulance first aid course. Nineteen students gained work experience at the Gardens in nursery practice, landscaping and general gardening. A highlight of the new education services offered by Mr Smith was *January in the Gardens*, a highly successful program of activities for the public which will be repeated. Approximately 200 people took part in a program of two activities each weekday in the month. Sessions included plant propagation classes, seed collecting and planting (native species), bird walks, nursery tours, craft sessions, garden tours, kitemaking, basketry and relaxation classes. All senior Gardens staff contributed to the program. Outside specialists invited to lead sessions included David Chandler (kite making), Heather Pearson (relaxation), Gwen Egg (basketry using natural materials found in the Gardens) and Mark Hurburgh, former Gardens Education and Information Officer (history walk). In August, 22 Friends of the Gardens attended a Volunteer Guide training course designed by the Education Officer.

Horticultural Therapist Mrs Pat Mavromatis was joined by Mrs Philomena van Ryswijk, Occupational Therapist, to share the work in the Easy Access Gardens project which has a steadily increased involvement with the disabled and other special groups outside the Gardens. An Easy Access Garden Room erected beside the raised beds area by vocational students from the Carpentry Division of the Hobart Technical College will be of great use in accommodating classes this coming year.

The Trustees, in collaboration with Mrs Mavromatis, Mr Cane, Senior Foreman and advisors from Disabled Support Groups, have started the development of a policy of access for all, aimed at modifications which will increase the ease, enjoyment and safety of all visitors to the Gardens including the disabled.

Stage III of the Technical Support Services Centre started in April is largely complete with the erection of the building housing the Senior Foreman's office, workshop and store, and the third multi-span glasshouse.

Further upgrading in the Gardens during the year includes extensive maintenance inside and outside the Conservatory, re-landscaping of the Tropical House and continued activities of Plant Recording Officer Mrs Susan Wells to the point that the Gardens is now one of the best labelled in Australia. A bus turning circle has been completed in the former car park above the main Gardens entrance. Plant and bird walks have been extended to include both morning and evening events and continue to delight increasing numbers of the public.

Acknowledgements

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery and the Queen Victoria Museum and Art Gallery are specially thanked for their help and co-operation.

We are grateful for the dedicated help given by members of the Council during the year.

O.M. Roe
Senior Vice-President

D.R. Gregg
Honorary Secretary

15 February 1990

THE ROYAL SOCIETY OF TASMANIA

Statement of Receipts and Payments for the year ended 31 December 1989

General Account

Balance 1 January 1989		3 658.30	Stationery		1 636.46
			Postage		1 863.37
Subscriptions			Copying		516.96
262 @ $20	5 236.00		Library books and subs		576.28
101 @ $12	1 212.00		Postbox rental		120.00
3 @ $ 8	176.00		*Papers and Proceedings* /publications		25 949.16
Other	328.00	7 852.00	Secretarial fees		3 565.23
			Bank duties/charges		82.85
Publication sales		5 104.21	Banks Medal and advertising		489.44
Curtis volume donations		1 000.00	Tasman Peninsula publication		10 456.73
Interest		3 051.42	*Papers and Proceedings* refund		52.00
Interest — other		122.71	Attendant fees		1 047.50
Rent		875.77	Northern Branch		1 500.00
Banks Medal sales		1 840.00	Insurance		343.74
Govt and University grants		5 000.00	Sundry		6.19
Banks Lecture refunds - postage		49.75	Computer equipment		3 436.53
Macquarie Island symposium		3 262.13	Travelling - lecturer		641.00
Investments redeemed		27 500.00			52 283.44
			Balance at 31 December 1989		7 032.85
		$59 316.29			$59 316.29

Accumulation Account

Balance 1 January 1989			61 292.17
Add	Net increase in valuation of publications and medals for sale	10 938.05	
	Net transfer from Trust Funds	2 098.21	
	Increased cash at bank	3 984.96	
	Net decrease in advance subscriptions	200.00	17 221.22
			78 513.39
Deduct	Decreased investments		27 500.00
Balance 31 December 1989			$51 013.39

ROYAL SOCIETY OF TASMANIA

Balance Sheet as at 31 December 1989

61 292	Accumulated Funds		51 013.39
326	Subscriptions in advance		126.00
	Trust Funds:		
2 677	— Clive Lord Memorial Fund	2 162.68	
4 487	— A.N. Lewis Memorial Fund	4 659.45	
2 068	— Morton Allport Memorial	2 160.83	
789	— A.A. Clark Bequest	823.54	
5 436	— Joseph Milligan Bequest	2 221.82	
2 952	— R.M. Johnston Memorial Fund	3 085.04	
1 292	— Henry Oliver Bequest	1 332.64	
2 963	— W.H. Hudspeth Memorial	3 068.51	
5 509	— Life Membership Fund	6 560.55	26 075.06
$89 791			$77 214.45

	Represented by:	
33	Cash on hand	33.00
	Cash at bank:	
3 658	— General account	7 032.85
4 013	— *Papers and Proceedings* account	4 418.30
931	— Clive Lord Memorial Fund	1 016.85
1 296	— A.N. Lewis Memorial Fund	1 415.30
860	Mortgage Loan	860.00
29 500	Commonwealth Treasury Bonds and Inscribed Stock (at cost)	2 000.00
7 000	Interest Bearing Deposits	7 000.00
15 000	Library (at valuation for insurance)	15 000.00
19 820	Publications (at seeling prices)	32 598.15
7 680	Medals (at selling price)	5 840.00
$89 791		$77 214.45

The Society owns works of art which have been donated over the years and which do not appear on the Balance Sheet. They are all housed in the Tasmanian Museum and Art Gallery and are covered by that organisation's insurance. A catalogue is available to members listing these works of art.

D.R. Gregg
Honorary Secretary

T.A.H. Knight, B.Bus., A.A.S.A.
Honorary Treasurer

INFERENCES CONCERNING THE DISTRIBUTION AND COMPOSITION OF PRE-CARBONIFEROUS ROCKS IN SOUTHEASTERN TASMANIA

by D. E. Leaman

(with seven text-figures)

LEAMAN, D.E., 1990 (31:x): Inferences concerning the distribution and composition of pre-Carboniferous rocks in southeastern Tasmania. *Pap. Proc. R. Soc. Tasm.* 124(1): 1–12. ISSN 0080–4703. Leaman Geophysics, GPO Box 320, Hobart, Tasmania, Australia 7001.

Interpretation of gravity and magnetic data in southeastern Tasmania indicates that blanketing post-Carboniferous rocks generally lie unconformably on late Precambrian rocks. Supporting evidence is provided by clasts of basement within overlying pyroclastics and till, and three boreholes.

Near Hobart, west of the Huon River and south of Bruny Island, deep troughs were filled with (?) Cambrian sequences with a significant volcanic component. Some ultramafics are present along the western margins. Relatively thin wedges of Ordovician-Devonian rocks are also implied, especially west of the Huon River. All rock-units are comparable with those exposed in western Tasmania.

The boundary between eastern and western Tasmania terranes occurs near Sorell and granitoids are dominant east of it.

Jurassic dolerite feeder locations have been controlled by basement structure, and doming at Cygnet is related to a thick syenite intrusion. Many modern topographic, or Tertiary structural patterns may be recognised in deep structures.

Keywords: basement, gravity, magnetics, southeastern Tasmania, structure.

INTRODUCTION

Southeastern Tasmania is defined here as the area south of the latitude of New Norfolk and east of the longitude of the Picton River (fig. 1). The surface geology is dominated by exposures of Permo-Triassic Parmeener Supergroup rocks and Jurassic dolerite. Minor intrusions of Cretaceous igneous rocks occur near Cygnet, and Tertiary volcanics and sediments are also present, much of the latter lying beneath the waters of Storm Bay and the Derwent estuary.

Pre-Carboniferous rocks are rarely exposed and all known occurrences are shown in figure 1. Three Mines Department boreholes have penetrated basal Parmeener glacigene materials to reveal altered Cambrian (?) volcanics at Glenorchy (Everard 1976), Precambrian phyllite at Woodbridge (Farmer & Clarke 1985) and contact-metamorphosed Mathinna Beds at Eaglehawk Neck (Gulline & Clarke 1984). An extension of, or splay from the Tamar Lineament must lie between Glenorchy and Pirates Bay, in order to account for juxtaposition of basements of western and eastern Tasmania affinities. The difficulty of predicting the location of this junction was stressed by Williams (1976). The fragments of information available suggest, for most of the area, a complex terrane comparable to that exposed in northern and western Tasmania. Knowledge and understanding of it may well have ramifications for mineral or petroleum exploration.

A small petroleum explorer, Conga Oil, acquired airborne magnetic data across the region and infilled parts of the state gravity data base during 1987. The author was engaged to interpret this data in terms of pre-Carboniferous materials and structural controls and, in particular, to identify sites which might contain Ordovician Gordon Group. Carbonates of this group are believed to have sourced minor oil seepages in the region of Bruny Island.

This paper reports current understanding of pre-Carboniferous materials based on that interpretation as integrated with other fragmental data sources.

GEOLOGICAL DATA

Occurrences of pre-Carboniferous rocks are shown in figure 1. These include Late Precambrian rocks near Hastings and along the Weld River, Cambrian volcanics along the south coast, and Ordovician Gordon Group carbonates at New River, along the Picton River, at Ida Bay and at Hastings. Devonian granite, of eastern Tasmania affinity, occurs near Pirates Bay. Cambrian (?) mafic and ultramafic rocks have also been observed along the

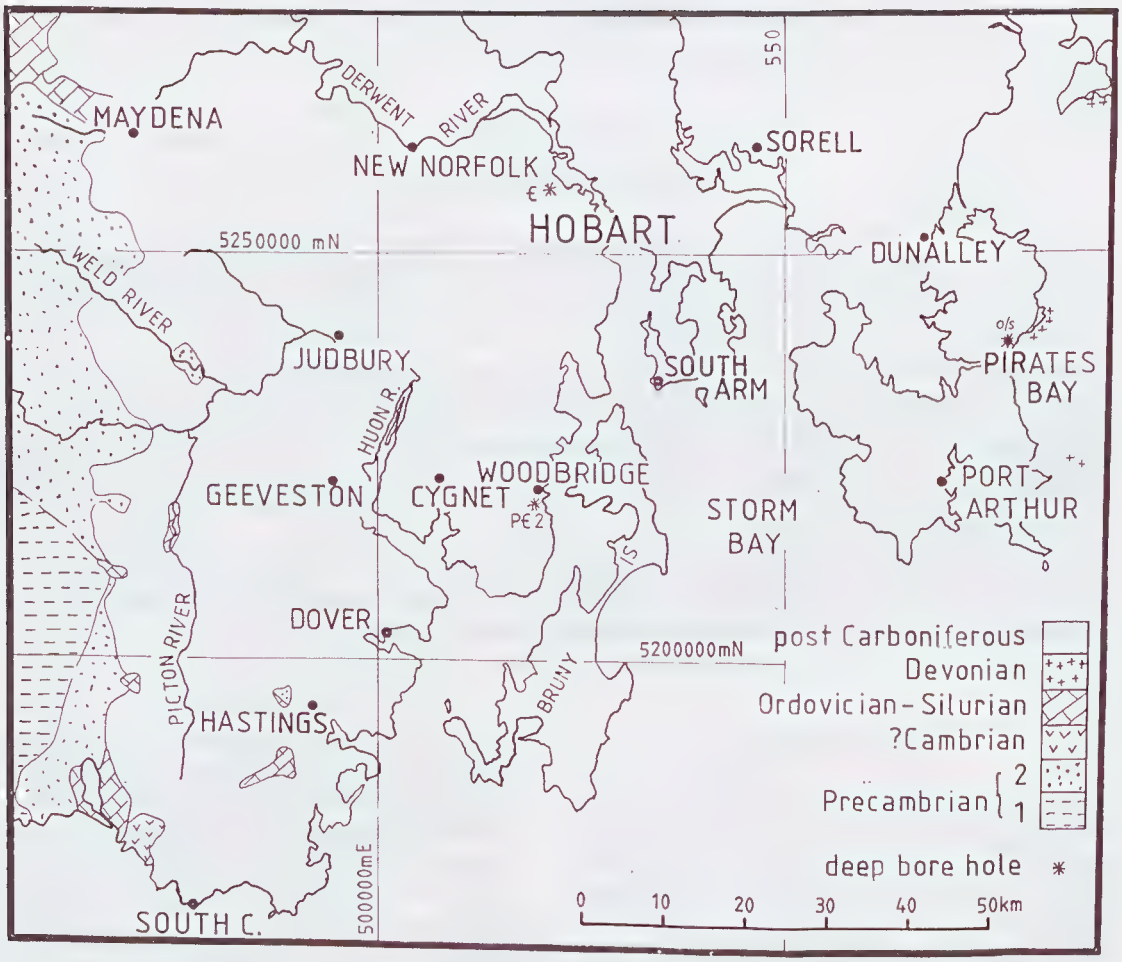


FIG. 1 — Locality map for southeastern Tasmania. All known exposures of pre-Carboniferous rocks are shown.

Weld River (T. Summons, K. Morrison, pers. comm.). Altered Cambrian volcanics occur at 600 m depth at Glenorchy (Leaman 1972, Everard 1976) and Precambrian phyllite underlies Truro Tillite at 998 m depth at Woodbridge (Farmer & Clarke 1985). The boreholes suggest minimum depths to pre-Carboniferous materials since the sites were specially selected. Another hole, at Cygnet, was abandoned after proving a tillite thickness in excess of 450 m (Farmer 1985). A hole at Eaglehawk Neck (Gulline & Clarke 1984) encountered a Mathinna Bedsadamellite contact at 398 m.

Basal Parmeener Supergroup formations are rarely exposed within the region and there are few opportunities to consider provenance of their contents. Although no rigorous study of the pebble compositions within the Truro Tillite has been completed at, or between, available exposures, Leaman & Naqvi (1968) and Banks (1981) have tabulated information on clast compositions. The tillites at Woodbridge and Cygnet are anomalous in a Tasmanian context; they are rich in igneous and Precambrian metamorphic material whereas clasts of many Palaeozoic sedimentary rock types, including limestone, are present but relatively rare. This anomalous enrichment implies passage of the ice sheet across a metamorphic terrane, winnowing, and/or a local predominance of such rock types, since it is known that the deposits are irregular and fill depressions in the Carboniferous topography. No tillite was found in the Glenorchy bore. In these conditions it might be expected that local rocks,

within a radius of 10–50 km, might have fed much of the basal units. The implied provenance of the tills at Woodbridge and Cygnet is also wholly consistent with the known rock types at depth, or exposed west of the Picton River or Maydena. Even so, the lack of pebbles of Palaeozoic sedimentary rocks is abnormal, given the relative proportions recorded elsewhere, the general distribution of Precambrian and Palaeozoic rocks and a presumed ice movement from the west or northwest (Clarke 1988). These anomalies may indicate a very local, less than 20 km, derivation and lack of Palaeozoic sedimentary rock exposure to the ice sheet. This scale of source range was suggested by Banks (1981) for material at Maydena but cannot be verified in the region southeast of Maydena due to lack of exposure.

It may be argued that clast content of tills several hundred metres above their base is not a reliable indicator of provenance or local basement. The relief of the filled terrain is comparable, however, with the horizon levels sampled and this is probably not a critical objection.

Pyroclastic rocks offer an alternative sampling of basement rocks. Few mappers, however, have recorded ejecta compositions and, unfortunately, most Tertiary volcanic activity is restricted to the region east of the D'Entrecasteaux Channel and Mt Wellington. Contents of some volcanic centres have been described by Sutherland (1976), Leaman (1976) and Farmer (1985). Some other centres have been inspected by the writer. Fragments of Parmeener Supergroup rocks or dolerite are common, although proportions vary at each vent. Only two sites inspected to date, at Acton and Risdon east of Hobart, present distinctive amounts of any other material — a quartz-veined phyllite comparable to basement in the Woodbridge bore. These observations can be considered definitive and representative of basement east of Hobart.

Although sampling by volcanoes or drilling is limited, it does suggest that exposures at Weld River and Hastings may be typical of pre-Carboniferous basement in southeastern Tasmania — Precambrian rocks but not of the Tyennan region (Turner 1988). This accords with the more ambiguous implication based on tillite clast observations.

GEOPHYSICAL DATA

Seismic, magnetic and gravity data are available for large parts of southeastern Tasmania.

The seismic method, potentially very informative, is of limited value due to energy transmission and processing problems. Much research will be required before generally acceptable results are achievable. Most of the region south of Tasman Peninsula, including Storm Bay, was surveyed by Amoco (Amoco 1971). Water depth and character in Recent and Tertiary sediments and sedimentary rocks are clearly presented. Seismic basement, usually dolerite or Permian rocks, is encountered at reflection times much less than one second, and all seismic records are thereafter degraded. The base of the Parmeener Supergroup is never recognised, nor is the base of any dolerite sheet. In each case the large velocity–density (acoustic) contrast should generate a strong reflection. Similarly disappointing results appear to have been recorded during a recent survey by the Bureau of Mineral Resources during 1988 (P. Hill, pers. comm). Onshore surveys present poorer source–receiver transmission conditions but yield similar results (e.g. Leaman 1978, Leaman & Richardson 1981). Most energy appears to be reflected by the uppermost dolerite surface with production of a seismic shadow. However, Leaman (1978) was able to find rare sites in which good reflections were recoverable from the surface to Moho depths. A site near Clifton, on South Arm, suggested that either the problems were not intractable or that different conditions applied.

Conga Oil recorded a test line on North Bruny Island during 1987; the results were consistent with previous surveys. True reflection character was barely discernible at about 0.4 and 2 seconds respectively. The remainder of the record was typical of noise or homogeneous non-reflective material. At the velocities observed, the upper character change might represent the sub-Parmeener unconformity.

Results such as that noted at Clifton suggest that the method is either generally unworkable south of Hobart, for various reasons, or that deep reflectors are generally absent. The second explanation would imply that post-Cambrian sedimentary rocks (Gordon Group for example), which are heterogeneous and contrasting in properties and would present strong acoustic contrasts, are not common. Further research is necessary before this judgment can be refined or modified.

The potential field methods, gravity and magnetics, offer the best opportunity for regional appraisal. Four regional magnetic surveys have been completed in the area (Finney & Shelley 1967, Esso 1967, Leaman 1987, BMR 1988). Only that undertaken by Conga Oil (Leaman 1987) is fully defined and suitable for detailed analysis. It also covers onshore and offshore segments of the region.

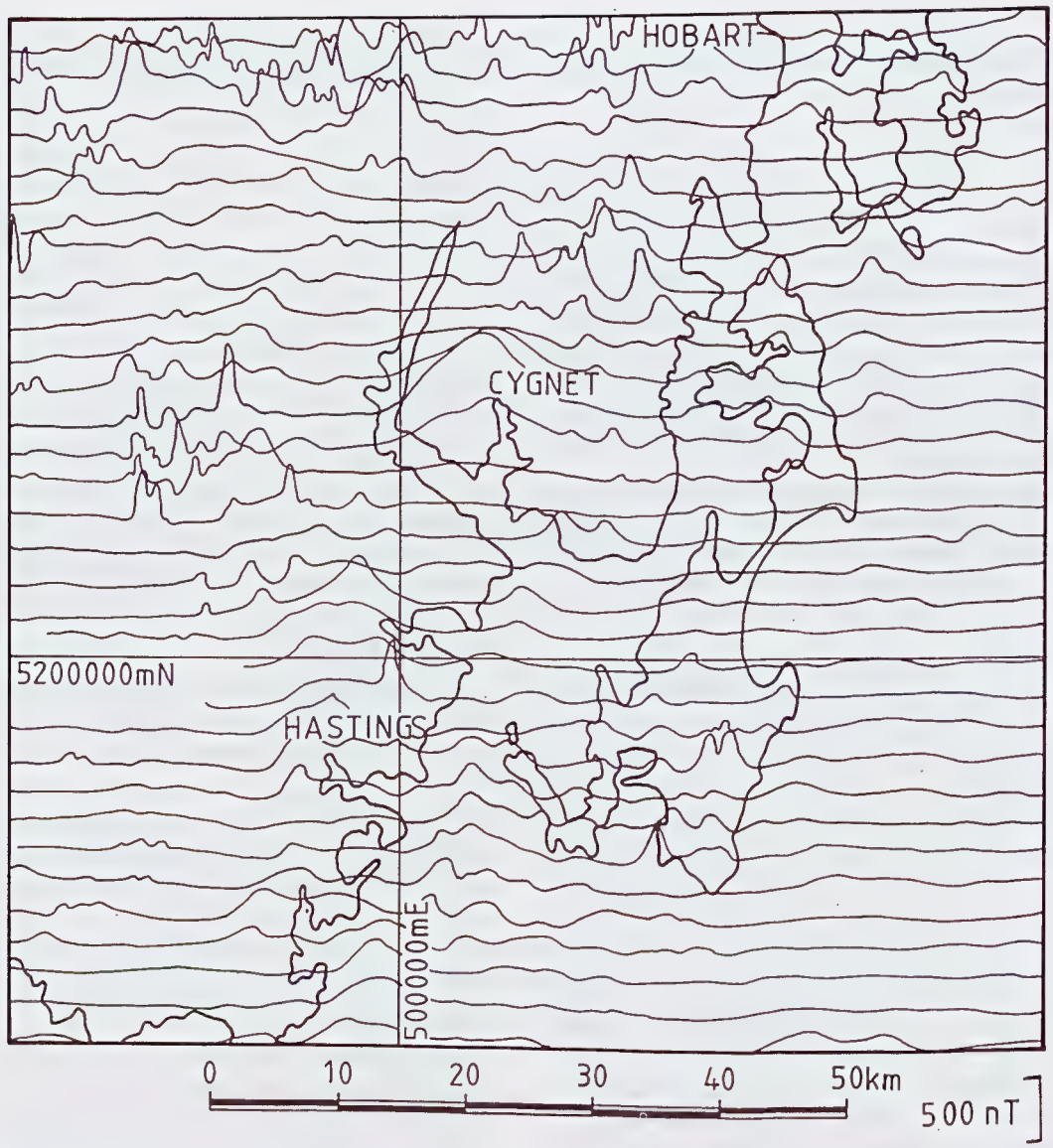


FIG. 2 — Magnetic profiles, 2.5 km apart, observed at 1000 m above sea level. The large Cygnet anomaly and tracts of magnetic basement are indicated by raised field intensity levels. Most high frequency character reflects dolerite-capped topography. Survey for Conga Oil.

Profiles of the magnetic field are shown in figure 2. The field was observed at an elevation of 1000 m a.s.l. and is generally free of any flight deviations. The figure stresses the characteristics of the magnetic field. Some areas contain large isolated anomalies, others extensive regional sources. Since the average terrain clearance was in excess of 700 m for most of the survey, only large, deep-seated or vertically extended sources are reflected in the data.

The gravity data base of Richardson & Leaman (1987) was infilled by Conga Oil to a variable but nominal station spacing of 2 km. The Bouguer map produced was compared to the state crustal model (MANTLE-88, Leaman 1988a, Leaman & Richardson 1989); the resulting residual anomalies are shown in figure 3. These reveal a broad belt of

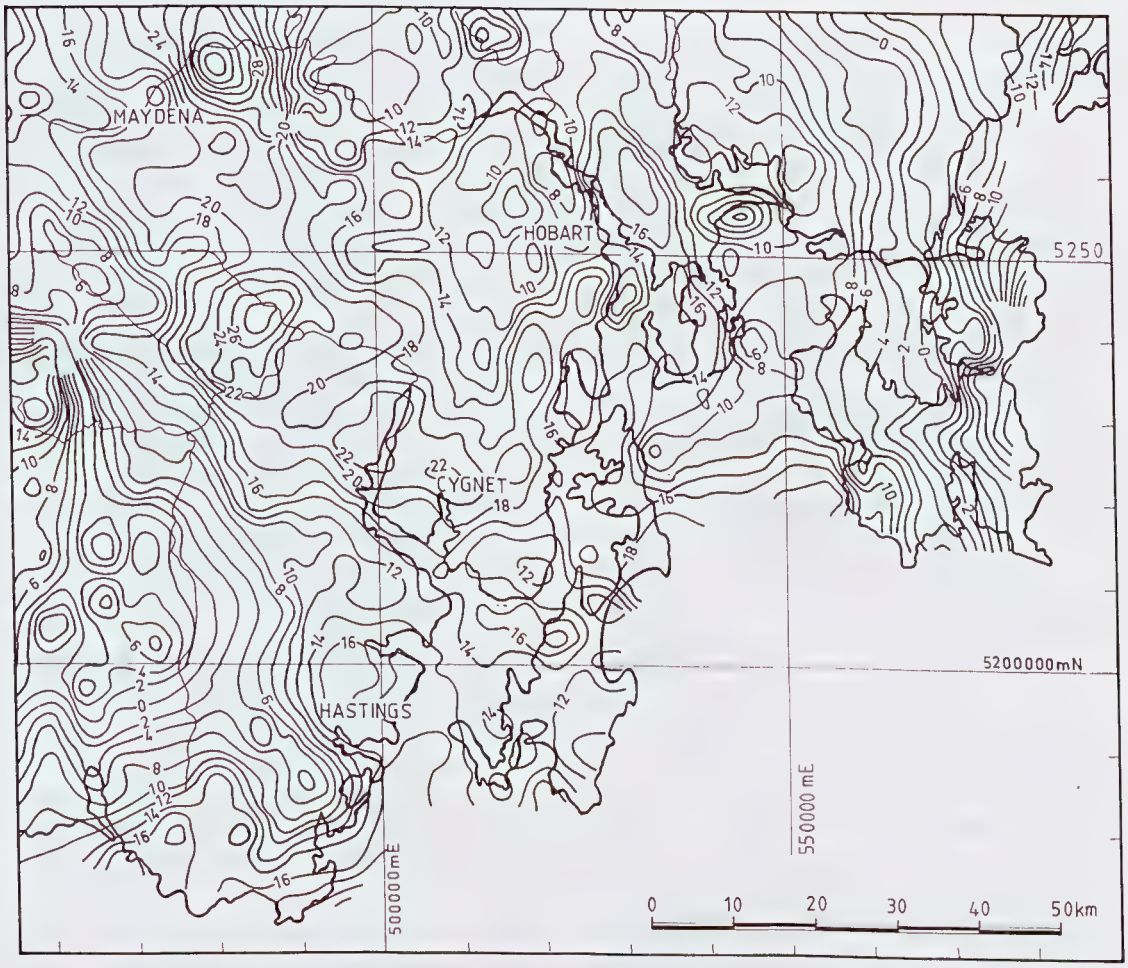


FIG. 3 — Residual Bouguer anomalies derived from observed Bouguer anomalies reduced at a density of 2.67 t/cu m after removal of crustal effects (see text). All data from Tasmanian Mines Department data base.

positive anomalies extending northwest from the Huon estuary.

Although trend information can be deduced from figures 2 and 3, or variations of them, each data set requires extended analysis before details of basement structure can be described reliably.

GRAVITY-MAGNETIC INTERPRETATION

Complete interpretive details and discussion are given by Leaman (1987) and only conclusions or critical aspects are presented here.

Quantitative modelling of both data sets was based on a N–S, E–W, NW–SE and SW–NE array of 17 interlocking profiles, and the solutions accepted were based on consistent profile matches and criteria for all data. Reliability of the interpretation is uniform south of 5255000 mN.

Figure 2 suggests that two distinct magnetic source types are present. Figure 4C illustrates the detailed character of the field and required sources and shows that the basic form of the profile is satisfied by a broad, deep, basin-like source of moderate contrast. Spiky elements reflect more local and shallower sources. The large spike doublet is part of the Cygnet anomaly (see fig. 2). The general response of the primary source is governed by its bulk contrast, depth range, marginal dips and depth to its upper surface. The depth range factor is least sensitive but must exceed 5–6 km. High frequency elements are related to dolerite or, exceptionally,

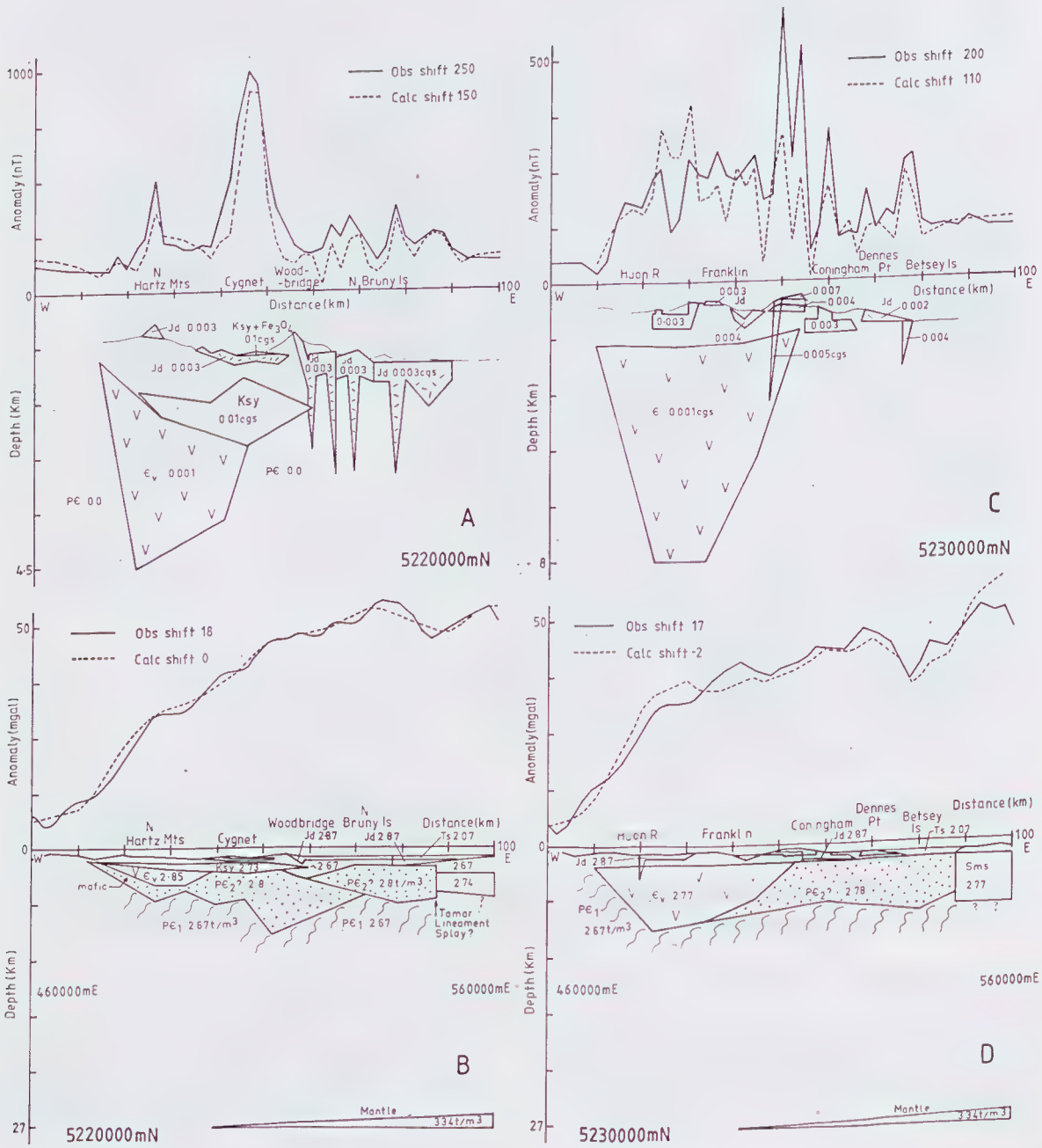


FIG. 4 — Typical magnetic and gravity interpretation models. (A, B) for E–W line at 5220000 mN, (C, D) at 5230000 mN. Symbols: Ts, Tertiary sediments; Ksy, Cretaceous syenite; Jd, Jurassic dolerite; Sms, Silurian Mathinna Beds; Dg, Devonian granite; Ev, Cambrian volcanic suites; pE_2, Jubilee region style Precambrian; pE_1, Tyennan region style Precambrian.

syenite (below). Only major changes in source geometry, especially those with sub-vertical aspects, can yield the field character observed after filtering by large terrain clearances. The precise character of each response is not easily reproduced by simple two-dimensional modelling but the style is definitive. Modelling of all profiles selected has shown that magnetic character is either of this binary type, large and deep sources with local shallow sources, or simply of the small source type.

Large, deep sources are restricted to distinct zones. Modelling also verifies that the marked, isolated anomalies, or spikes, evident in figures 2 and 4 are related to large dolerite dykes or feeder pipes with vertical ranges of at least 2 km. Only a small part of the observed responses can be associated with property or contrast change such as induced by the presence of granophyric or other extreme differentiates; the geometric factor is paramount.

Figure 4D presents the equivalent gravity solution. Some potentially ambiguous elements are minimised or resolved by the magnetic information. The gravity models of figure 4B and D are based on the observed, not residual, Bouguer anomalies and the crustal aspect of the model is therefore included.

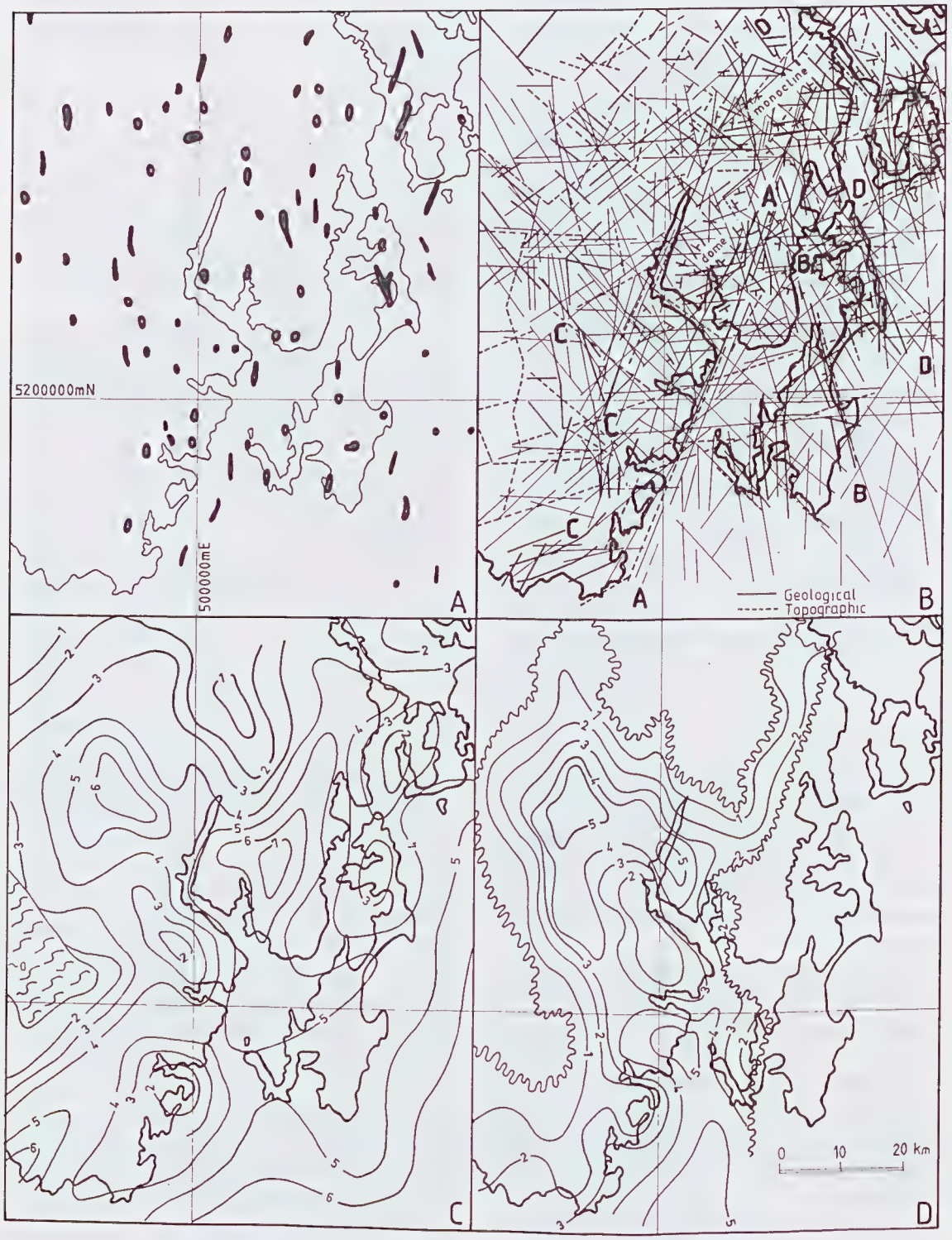
The large magnetic anomaly centred on Cygnet has long been known and always assumed to be associated with the Cretaceous syenite complex (e.g. Finney & Shelley 1967, Leaman & Naqvi 1968) although the precise origin has been debated. The anomaly correlates with a domal structure in the Cygnet region. Regional modelling of typical profiles shows that the Cygnet anomaly also has two source components; one near surface and of extreme contrast and another of large volume and moderate contrast at moderate depth. The near-surface source is volume limited and consistent with the alteration products, including free magnetite and pyrrhotite observed around Port Cygnet. The deeper source extends northeast toward Woodbridge, as does the syenite dyke swarm.

Figure 4A suggests the magnitude of the source. A laccolithic syenite pod 750 m thick, with lateral extent suggested, emplaced at the base of the Truro Tillite, would be able to generate the doming observed around Cygnet. Such a pod also accounts for the anomalous regional metamorphism recorded by Leaman & Naqvi (1968) and Farmer (1985: 69). This new analysis shows that Leaman & Naqvi (1968) were correct in inferring a large laccolithic form but misplaced its location. Their use of the term hybrid for the alteration, especially of dolerite, south of Cygnet was misunderstood by Farmer (1985) who then failed to appreciate the significance of the metamorphism described. The roof of the laccolith may lie close to, or in the highly altered dolerite sheet exposed near Cygnet. The dyke swarm pattern appears to reflect anisotropic extension of the roof rocks.

The equivalent gravity profile (fig. 4B) indicates that the general increase in anomaly amplitude eastward is due partly to the presence of the magnetic rocks, but the effect is sustained by non-magnetic, dense materials further east. The crustal contribution is minimal on this line. The relationship between anomaly and exposed Tyennan region basement west of the Picton River suggests that this lithology is representative of ultimate basement at a general depth of about 5 km.

The combined analysis enables conversion of the magnetic field data (fig. 2) into a plan of dolerite feeder locations (fig. 5A), the reliability of which is limited only by survey specification. Most elements of dolerite intrusion form can be deduced from the two data sets, although inferences based on only one data set can sometimes be misleading. The strong anomaly near Betsey Island, first noted by Flinders and marked on marine charts ever since, is due to a large feeder system.

Modelling has also established that the dense, magnetic sequence is only present in parts of the region. Figure 4 shows this to have the form of a deformed onlapped or rift trough fill. The upper surface is generally at a depth consistent with the base of the Permo-Carboniferous sequence after allowance for normal formation thicknesses. Although tillite estimates are uncertain it seems likely that the tillite or basal formations either overlie the magnetic units directly or are separated by less than 500 m. Non-magnetic Gordon Group formations must be thin, if present. Although the magnetic sequence is not universally present, the response pattern can be traced to the south coast, where it is associated with exposures of mafic Cambrian units, or to Glenorchy, where altered (?) Cambrian volcanics were found to underlie Permian rocks. The principal belt of these presumed Cambrian rocks extends NW–SE from the Weld River to Hastings (fig. 2). The entire gravity-magnetic pattern is similar to that observed in western Tasmania, between the coast and the core of the Tyennan region east of the Birch Inlet–Elliott Bay axis, but as a mirror image (Leaman 1988b). The inferred rock properties are consistent with a predominantly mafic assemblage such as the Crimson Creek Formation and its correlates (Brown 1988). A secondary belt of such rocks extends from Cygnet toward Hobart but the greatest development lies south of Bruny Island. Review of the magnetic data from these volcanic sequences has shown that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monocline
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Geological
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some localities contain materials with bulk contrasts consistent with ultramafics. These are restricted to the western side of the Huon trough axis west of Geeveston and also near the Weld River.

The remainder of the basement is non-magnetic but quite dense, at least to depths of 3–5 km, in much of the region. The non-magnetic basement properties can be traced eastward from exposures west of Maydena and northwest of the Picton River. The properties and patterns are consistent with an ultimate, siliceous Tyennan-region-style Precambrian basement, generally overlain by a Jubilee-region-style Precambrian basement, such as exposed near Maydena (Turner 1988).

Figure 5C and D summarise the interpretation in terms of Cambrian and Precambrian units. The trend patterns (fig. 5B), compiled from the data sets and post-Carboniferous structures to indicate frequency of recognition and importance, can be compared with old trough structures. Any differential between the upper surface of siliceous basement and the base of the volcanic units is a measure of the thickness of presumed Jubilee region rock types (also fig. 6). The relationships are similar to those observed or inferred in northwestern Tasmania (Leaman 1988b).

DISCUSSION

Several strands of evidence and information have been utilised to obtain an indication of the constitution of the concealed pre-Carboniferous basement in southern Tasmania. There is much scope for refinement.

The Tertiary, Cretaceous and Jurassic igneous rocks, while not strictly part of the topic of this paper, occupy some of the volume below the Carboniferous unconformity. It could also be expected that their emplacement has been at least partly controlled by older structures. For example, several large dolerite feeders lie near the eastern edge of the Cambrian belt from Ferntree to Red Hill and Garden Island Creek; so does the Cygnet alkaline intrusion. Compare figure 5A, C and D. Figure 5C clarifies an issue raised by Leaman (1972). The gravity field in the region of Mt Wellington was considered locally negative and not explained by known materials or possible deficiencies in terrain corrections. The observations were thought to indicate a granite stock in basement, which also forced subsequent extensional fracturing to pass around this region. A local basement high composed of siliceous Precambrian materials, with a relief of several kilometres, surrounded or onlapped by a denser sequence would produce a similar effect. It is also possible to speculate on the origin of the only zone in the Hobart district with easterly dips. This lies between the city and Mt Wellington and includes several junctions involving large Tertiary and Jurassic movements, as well as overlying the pinched northern extension of the Cambrian trough. The dips may reflect a continuing process of rejuvenation of the old basement core beneath the Wellington tableland to the west (fig. 5C).

General inferences concerning the distribution and relationships of principal basement types are shown in figures 6 and 7. The basal Permian or Upper Carboniferous formations may generally overlie either Cambrian volcanics or Precambrian phyllites and units comparable to those of the Jubilee region. The gravity-magnetic interpretation is consistent with available pyroclastic and drilling data and the common seismic result. Nearly all seismic surveys have been undertaken where all the other methods imply a Precambrian basement beneath the unconformity. This would account for the general absence of deep reflections. It also explains the faint 2-second event observed on Bruny Island. This is equivalent to a depth of about 4 km, the level inferred for the interface between Precambrian units using gravity data.

Figures 6 and 7 also suggest sites where post-Cambrian veneers might be present but this aspect of the interpretation is most uncertain. No gap in excess of one kilometre has yet been inferred between the nominal base of Truro Tillite and Cambrian or older rocks, and much of the apparent gap could be subsumed by false assumptions concerning the amount of tillite in the particular area. It is possible to systematically trace a wedge of Gordon Group from the Picton River toward the Huon River but nowhere else.

The implied limited distribution of Gordon Group materials west of the Huon River, or as very thin

FIG. 5 — Summary of gravity-magnetic interpretation results: (A) Jurassic dolerite feeders, location and shapes as defined by available data; (B) compilation of all trend information (firm and broken lines represent post-Carboniferous or topographic features; fine lines represent features identified by gravity or magnetic data); (C) combined gravity-magnetic interpretation of depth to top of Tyennan-region-type Precambrian basement; (D) interpretation of depth of base of (?) Cambrian volcanic sequences (all contours in km below sea level).

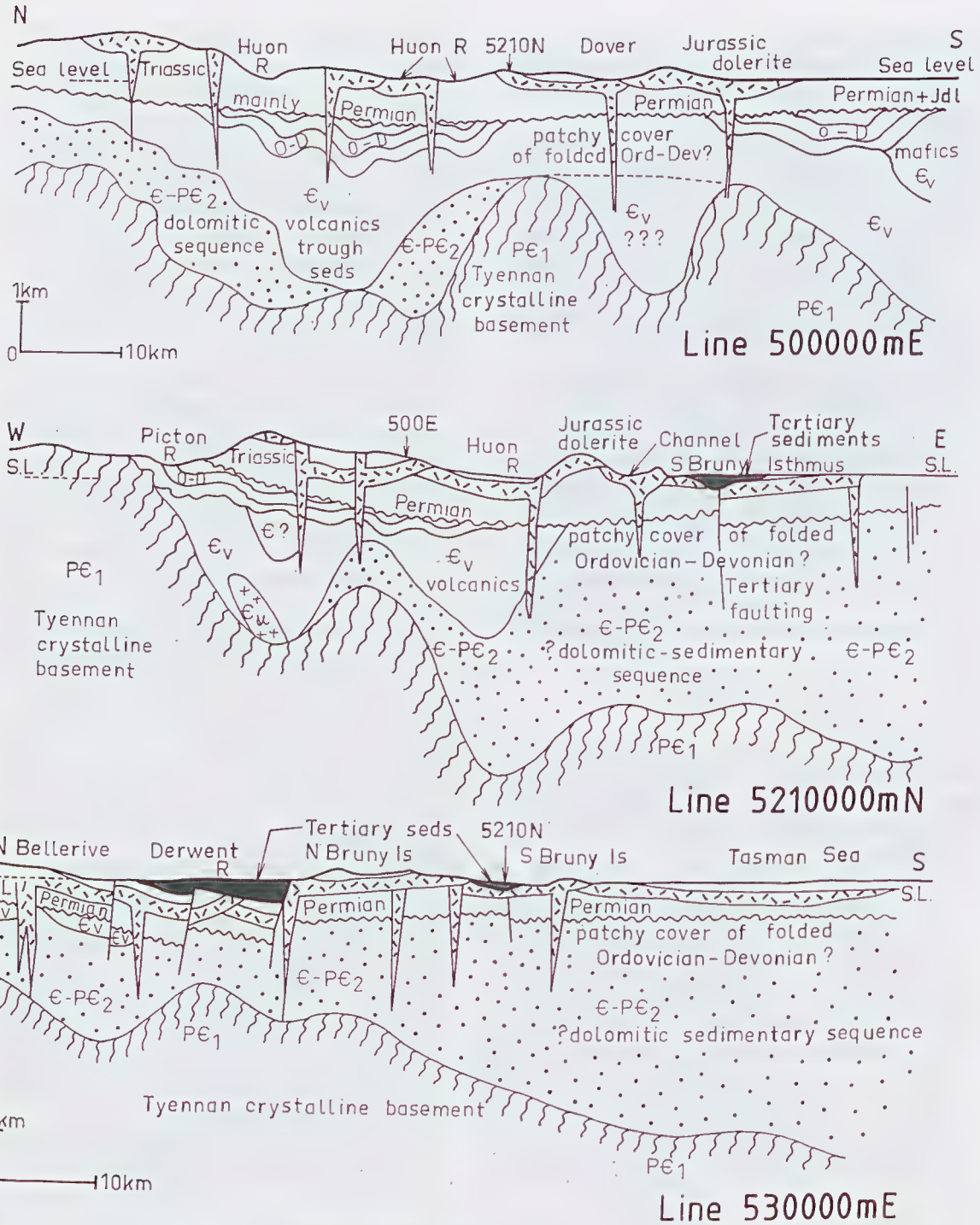

FIG. 6 — Representation of geophysical interpretation as conventional geological sections; symbols as figure 4. Phyllite drilled at Woodbridge is considered representative of E-pE_2 (Jubilee-region-style Precambrian).

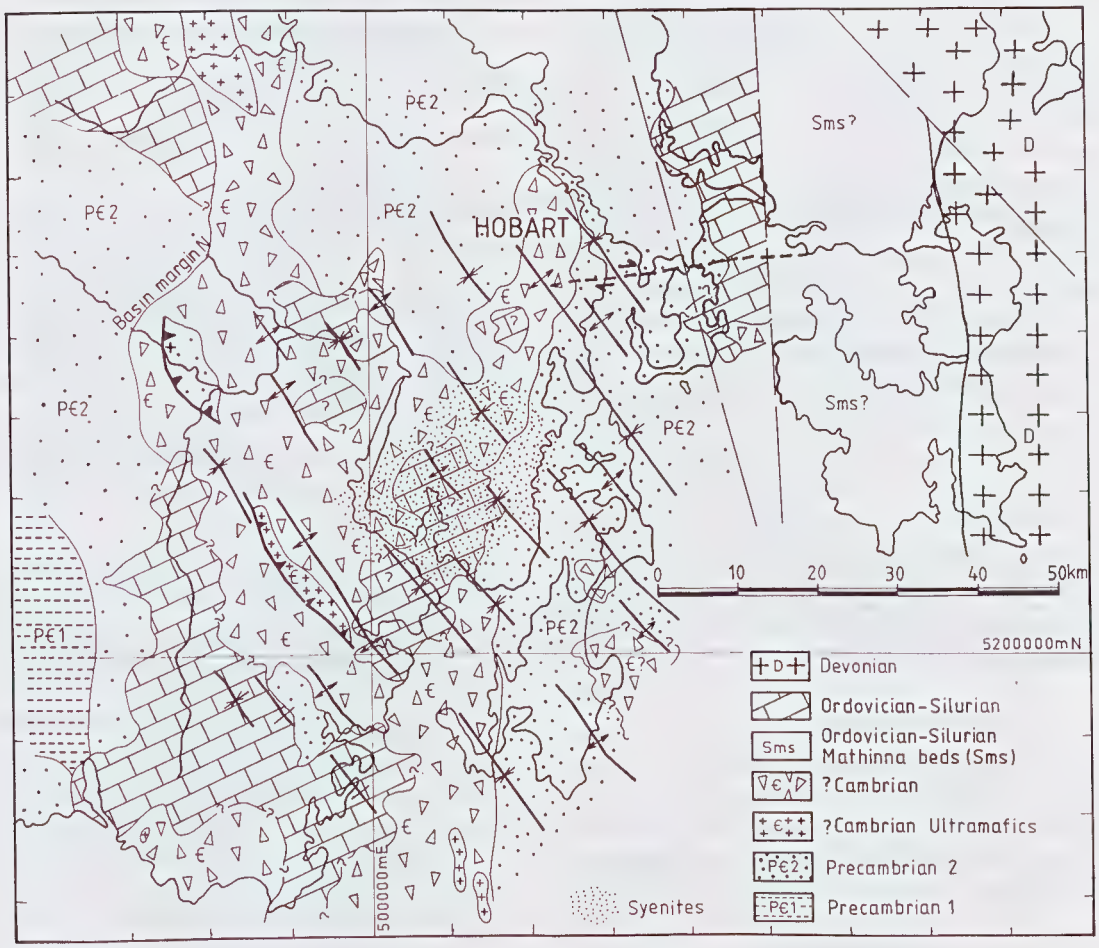

FIG. 7 — Distribution of inferred basement rock types at the base of the Parmeener Supergroup. The distribution of post-Cambrian Palaeozoic units is not well established and these may be present only as small patches. Possible regional fold trends and thrusts indicated in interpretation are shown.

veneers elsewhere, would account for the extraordinary bias toward metamorphic and igneous rocks in the Carboniferous tillites in southeastern Tasmania.

Several aspects of post-Carboniferous structuring and terrain development have long appeared enigmatic. These include the trend changes of the Huon and Derwent estuaries and the Derwent crosscut between New Norfolk and Bridgewater. No obvious post-Carboniferous controls or structures are present. Figure 5B shows that such features, and many coastal outlines, reflect basement features. Trends evident in regional gravity and magnetic data delimit major basement boundaries, and these have been impressed or rejuvenated periodically. Many direct correlations are apparent, while other relationships can be inferred. The dextral offset shown in figure 7 near Hobart is an example. This feature corresponds to many cross-trends (fig. 5B) and several Jurassic dislocations lie along it. Tertiary basin trends swing from NW–SE north of it to NE–SW south of it. Basement structural control is indicated.

Dolerite feeders can be associated with the form and changes in marginal gradients of the (?) Cambrian trough where present (fig. 5C, D) and with fracture-trend concentrations elsewhere (fig. 5B). Some major trends identified by all data sets and which imply a substantial ranging source depth, are labelled in figure 5B.

Williams (1976) suggested that the possible extension of the Tamar Lineament might occur east of South Arm. Gravity and magnetic data in the Storm Bay region do indicate a change in basement composition at the longitude of Sorell. Figure 3 shows that this is not due to the presence of granitoids. The western face of the adamellite complex lies at the longitude of Port Arthur and Dunalley and is marked by N–S coastal features. This relationship also suggests continual renewal of structural boundaries. The interpretation (fig. 7) suggests that northeast of Sorell the granitoid margin is offset to the northwest. The margin then continues N–S through the eastern midlands. The change in basement composition inferred on the eastern side of Storm Bay occurs where the margin in the midlands would occur if projected southward. Since the entire granitoid intrusion pattern indicates fracture control, the original fracture would appear to have been preserved south of Sorell. It is possible that the block between this projection of the granite margin and its actual margin at Port Arthur is composed of Ordovician-Devonian Mathinna Beds and possibly granodiorite, as occurs west of Scottsdale.

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DRINK DRIVERS AND THE COURT PROCESS IN HOBART: A SUMMARY FOR 1000 OFFENDERS

by L.J. Wood

(with nineteen tables and one text-figure)

WOOD, L.J., 1990 (31:x): Drink drivers and the court process in Hobart: a summary for 1000 offenders. *Pap. Proc. R. Soc. Tasm.* 124(1): 13–25. ISSN 0080–4703. Department of Geography and Environmental Studies, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001.

The paper examines the personal characteristics, previous drink driving records, entry to the courts and court decisions for 1000 offenders convicted in the Hobart Courts of Petty Sessions for alcohol-related driving offences. It is shown that southern Tasmania has a very high rate of recidivism, that a large proportion chose legal representation and that the sentences of individual magistrates vary substantially even when a large number of factors are held constant. It is suggested that solicitors use adjournments to steer clients towards particular magistrates and some options for review of the current system are outlined.

Keywords: drink driving, recidivism, court sentences.

INTRODUCTION

Analyses of crime are commonly frustrated by a lack of data. Official statistics (for example, ABS 1986) give broad overviews but are of limited value for detailed investigations of specific offences or types of offenders. Authorities with access to information, the police, road safety, prison and probation services, and the courts, rarely have the resources to produce more than gross summaries. Yet detailed examinations are important for at least two reasons. First, knowledge of offender characteristics is vital for the design and implementation of crime reduction strategies. Second, court sentences need to be scrutinised in order to identify any apparent disparities. It has been claimed that the courts "... want statistical information on their current sentencing practices" (Lovegrove 1987: 211). In noting that the major part of police effort and lower court time is probably spent on traffic matters, a Hobart magistrate claimed that, in Tasmania, "... there has been no effective monitoring of this tremendous expenditure of public time and resources" (Sikk 1985: 156).

This paper aims to fill part of the gap. It focusses on the most common offence treated in Tasmanian courts, drink driving, of which well over 4000 cases per annum are heard (ABS 1986). Detailed studies of drink driving, particularly examining the effects of random breath testing (RBT), are available for some mainland states (for example, Cashmore 1985), but material for Tasmania is sparse. Madden (1986) has provided a brief outline of the introduction of RBT to the state. Wood has examined variations in offender rates and penalties between Hobart suburbs (1987), in offender rates for local government areas (1989a) and in court decisions between the three benches that comprise the Tasmanian lower court system (1989b) .

DATA SOURCES AND AIMS

For this study, data were collected with the assistance of the Tasmanian Police Department. From January 1987, a set of details was recorded for slightly over 1000 drink driving offenders apprehended in southern Tasmania and eventually convicted by the Hobart-based Court of Petty Sessions. Details included name, age, sex, place of residence, place and date of arrest, occupation, blood alcohol concentration (BAC), ancillary offences (i.e. offences other than drink driving with which the offender was simultaneously charged), presence or absence of legal representation, number of adjournments before sentence, presiding magistrate, date of conviction and court penalty. Data were cross-checked by reference to press reports of drink driving convictions which include name, address, age, BAC and penalty for all offenders. Police and press records rarely differed, although obviously not all details could be checked. Information on the previous drink driving convictions of each offender (generally referred to below as priors) was collected by the author from file cards maintained by the Breathalyser Unit.

The data problems need to be acknowledged. First, the original intention was to have data collected for the first 1000 offenders to be convicted from January

1987. Through work pressure, the police were not able to meet this aim and there were some periods when details were not recorded. There is no means of testing for bias in police recording but neither is there reason to suspect it. Second, although the record of priors was begun in the early 1970's, there were some indications that it was not totally accurate. This applies particularly for offences committed in other police jurisdictions. Errors are likely to be on the side of under-recording. Third, as with any laborious recording exercise, some details were missing and not retrievable.

Despite these drawbacks, the data provide information that has not previously been available for Tasmania. The initial list was pruned to 1000 by including only the last offence of the few individuals who appeared more than once during the data collection period and randomly deleting four others.

Data are presented under four headings: personal characteristics; prior records and the characteristics of the offence that brought offenders into the sample; entry to the court system and, finally, the court decision. Some parallels are drawn with mainland studies. The emphasis is on description rather than multiple cross-tabulations, in the belief that there is a need for baseline information. However, particular weight is given to prior records and the role of the individual magistrate — two factors shown to be of major importance in mainland studies.

PERSONAL CHARACTERISTICS OF OFFENDERS

Young, unskilled or unemployed males are heavily represented in Australian drink driving conviction statistics (Homel 1981). This statement certainly applies to Tasmania where 85.5% of the sample was male. Figures for NSW from 1977 to 1983 showed in excess of 93% of convicted drink driving offenders to be male (Cashmore 1985). The slightly lower figure for Tasmania may reflect a randomising influence of RBT (introduced to the state in 1983). Cashmore also shows that 39.8% of convicted offenders in NSW in 1983 were men under the age of 25. The age breakdown for Tasmania shows 42.3% of the sample in this category (table 1).

In terms of occupation, 43.1% of the sample were either unemployed or in the "Labourers and Related Workers" category (table 2). By contrast, the high-status managerial, administrative, professional, and paraprofessional occupations, employing 30.3% of Hobart's labour force in 1986 (Kennedy *et al.* 1989), provided only 9.2% of offenders.

TABLE 1
Age and Sex Composition of 1000 Convicted Drink Driving Offenders, Hobart 1987

Age	Male		Female	
	No.	%	No.	%
<20	131	15.3	16	11.0
20–24	231	27.0	47	32.4
25–29	169	19.8	33	22.8
30–34	98	11.4	22	15.2
35–39	69	8.1	13	9.0
40–44	68	8.0	8	5.5
45–49	39	4.6	5	3.5
50–54	26	3.0	0	0
55–59	12	1.4	1	0.7
60–64	5	0.6	0	0
65–69	5	0.6	0	0
>69	1	0.1	0	0
Total	854	100.0	145	100.0

TABLE 2
Occupations of 1000 Convicted Drink Driving Offenders, Hobart 1987

Occupation	No.	%	% represented by a solicitor
Managerial/admin.	39	3.9	87.2
Professional	23	2.3	73.9
Para-professional/technical	34	3.4	70.1
Trades and related	121	12.1	60.3
Clerical	54	5.4	59.3
Sales and personal services	92	9.2	63.0
Plant operators	58	5.8	79.3
Labourers and related	230	23.0	53.9
Unemployed	201	20.1	56.2
House duties	31	3.1	48.4
Retired pensioners	12	1.2	83.3
Other pensioners	34	3.4	52.9
Student	27	2.7	55.6
Defence forces	3	0.3	66.7
Not stated	41	4.1	73.6
Total	1000	100.0	67.4

The factors that lead to a strong representation of young, unskilled/unemployed males in drink driving convictions have been subject to some debate. One perspective is that high-status groups "... are more deterred by the threat of legal and informal punishment" (Andenaes 1978, in Homel 1986: 134). By contrast, Homel suggests that the over-representation "... may, to a considerable degree, be a function of selective police practices" (1986: 12).

A factor that has received little attention in the literature is the home location of offenders. Previous work in Hobart has shown that newer, peripheral, public housing estates have very high offender rates (Wood 1987). Changed census boundaries make direct comparisons impossible. However, the nine suburbs in which more than 20% of housing was public rental in 1986 contained 16.9% of the city's population but 42.7% of the offenders resident in the metropolitan area. By contrast, the nine suburbs with less than 1% public housing had comparable figures of 27.4% and 32.2%.

This is not to suggest that public housing *per se* is a predictor of likelihood to offend. Rather, such areas tend to contain clusters of people with high scores on various risk factors (low incomes, high proportions unskilled or unemployed, large young male population, etc.). High offender rates for these areas may reflect subcultural differences in attitudes towards drinking and driving. They may also reflect locational disadvantage. Typically the newer estates possess few licensed premises, with the implication that intending drinkers must travel relatively long distances. Late-hour public transport is limited and low incomes mitigate against taxi usage. In addition, most of the estates, planned for virgin broadacre sites, are connected with the city proper by only one or two main roads. These locational factors make policing relatively easy though it is a moot point whether the net result is considered as biassed surveillance.

CURRENT OFFENCE AND PRIOR RECORDS

The offence which caused offenders to become part of the current sample is referred to as the current offence. In Tasmania, driving with a BAC of over 0.05% constitutes a breach of the law. However, with one exception, the police do not prosecute unless the alcohol reading exceeds 0.06%. The exception relates to first-year drivers (FYD) for whom any blood alcohol constitutes an offence. In fact there are four main alcohol-related driving charges. These are exceeding 0.05%, exceeding 0.0% for FYD, driving under the influence (DUI) and refusing breath analysis (RBA). DUI offenders often come to police attention through erratic driving. Only seven RBA charges emerged in the sample. Most of the RBA offenders were blood tested and eventually also charged with DUI.

Table 3 gives the BAC distribution for the total sample and for persons convicted for FYD and DUI. Readings under 0.07% mostly represent FYD but many FYDs had much higher values. Some, in fact, were simultaneously charged with DUI.

Whilst exceeding a prescribed BAC is the common element for all offenders, it is not uncommon for people to be simultaneously charged with a number of offences. In all, 34.5% of offenders were charged with offences in addition to exceeding the prescribed BAC. These additional offences may or may not be alcohol-related. Information on number and type of charges is of significance, since it may contribute to

TABLE 3
Blood Alcohol Concentrations for the Total Sample and for Persons Convicted for FYD and DUI, Hobart 1987*

BAC (%)	Total sample	FYD	DUI
<0.07	37	29	3
0.07	108	15	–
0.08	107	10	–
0.09	107	7	1
0.10	115	11	4
0.11	102	15	4
0.12	85	12	5
0.13	62	6	2
0.14	56	3	10
0.15	49	8	10
0.16	43	3	5
0.17	43	5	17
0.18	22	2	4
0.19	11	1	5
0.20	14	–	5
0.21	10	–	5
0.22	5	–	2
0.23	8	2	8
0.24	7	–	7
0.25	5	–	5
0.26	2	–	1
0.27	1	–	1
Total	999	129	104

* In a few cases, the police record merely indicated > 0.05. These were entered as < 0.07 which explains the discrepancy between the FYD and total columns.

differences in court sentences for people with similar BACs and prior records. However, description of charge patterns is complicated by various issues. Firstly, a very wide range of combinations is possible. Secondly, some charges generally subsume others. For example, DUI is regarded as more serious than exceeding 0.05%, yet a person may be charged with both. With the exception of FYDs with BACs below 0.07%, all offenders were charged with exceeding 0.05%. Table 4 gives a bald summary of the additional charges, broken down by alcohol-related and other offences.

The tallies refer to the number of people charged with each offence. Some individuals were charged with several offences in a particular category (e.g. false name and failing to appear in court). A not-inconsiderable number were charged with multiple additional offences, with the extreme being an individual charged with RBA, DUI and seven other offences. Not surprisingly, most of the other charges are related to motoring offences. Most common is the "unlicensed" category reflecting offenders who have never been licensed or whose license has been suspended, cancelled or disqualified.

In 8.7% of all cases, an accident brought offenders to police notice; 49 of these offenders were charged with additional offences, the most common of which was FYD.

The prior record of offenders is of major significance to the courts. It is considered here in terms of the number of previous drink driving convictions (priors) and the timing of those offences. Over 42% of the sample had at least one prior conviction for drink driving (table 5), a finding that contrasts strongly with evidence from elsewhere.

Sanson-Fisher *et al.* (1986), reviewing Australasian literature, indicate that about 75% of drink driving convictions are first offences. One other source (House of Representatives Standing Committee on Road Safety 1980) indicates that eventually between 20% and 25% of convicted drink drivers are reconvicted for the same offence. Possibly the method of data collection was biassed towards repeat offenders but, even with some bias, the figures suggest a higher proportion of multiple offenders in Tasmania than the national norm. This may indicate greater recidivism and/or more thorough policing in that State.

The temporal pattern of priors shows a wide range of variants on a theme. Figure 1 and tables 6 and 7 give part of the picture. Over 20% of all recidivists had had their most recent prior within about 18 months of their current conviction, and 50% within about three years. Conversely, a small proportion of recidivists (10.4%) showed relatively long arrest-free periods, with their most recent prior being before 1980. The highest proportion of very recent offences was evident for those with more than two priors. Of offenders with more than one prior, exactly half had first convictions dating from before 1980, which suggests relatively long participation in drink driving.

From discussions with police and convicted offenders, it is clear that there is enormous variation

TABLE 4
Number of People Charged with Additional Alcohol and Other Offences, Hobart 1987

Type	No.
Alcohol-related offences	
RBA	7
DUI	105
FYD	131
Other (e.g. consuming alcohol in a moving vehicle)	4
*Other offences**	
Driving fault (e.g. fail to stop at red light)	29
Driving manner (e.g. negligent driving)	47
Illegal driving (e.g. unregistered car)	10
Unlicensed (e.g. driving whilst licence disqualified)	99
Non-traffic offence (e.g. giving false name)	33
Others and inadequately recorded	8

* Other offences are classified largely on the system used by Hagger & Dax (1977).

TABLE 5
Prior Convictions for Drink Driving Offences, Hobart 1987

Number of priors	Offenders	
	No.	%
0	571	57.1
1	235	23.5
2	112	11.2
>2	82	8.2
Total	1000	100.0

TABLE 6
Date of Most Recent Offence for Recidivists, Hobart 1987

Year of Conviction	Number of previous offences							
	One		Two		>Two		Total	
	No.	%	No.	%	No.	%	No.	%
1986/7	52	22.2	17	15.2	22	26.8	91	21.0
1985	45	19.2	20	17.8	11	13.4	76	17.5
1984	40	17.1	20	17.8	17	20 .7	77	18.4
1983	26	11.1	15	13.4	9	11.0	50	11.5
1982	11	4.7	12	10.7	8	9.8	31	7.1
1981	13	5.6	5	4.5	10	12.2	28	6.5
1980	8	3.4	6	5.4	1	1.2	15	3.5
Before 1980	31	13.3	11	9.8	3	3.7	45	10.4
Not recorded	8	3.4	6	5.4	1	1.2	15	3.5
Total	234	100.0	112	100.0	82	100.0	428	100.0

TABLE 7
Date of Earliest Offence for Multiple Offenders, Hobart 1987

Year of Conviction	Number of Previous Offences		
	Two	>Two	Total
1986/7	2	1	3
1985	9	1	10
1984	5	3	8
1983	14	2	16
1982	11	6	17
1981	9	5	14
1980	10	8	18
Before 1980	44	53	97
Not recorded	8	3	11
Total	112	82	193

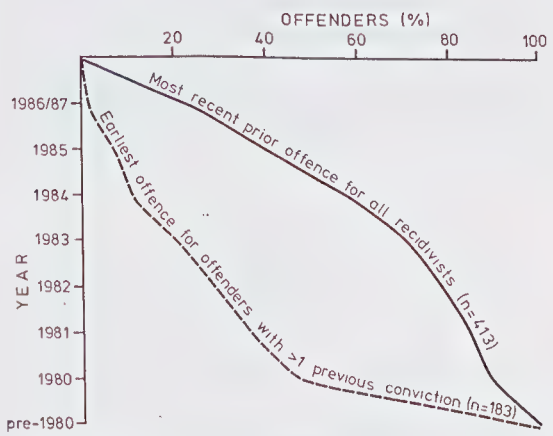

FIG. 1 — Timing of previous offences. The data exclude 16 persons for whom a prior record was known to exist but for whom specific details were not available.

in case histories. People with two convictions range from the genuinely unlucky — represented, perhaps, by the individual who has driven over the limit twice in ten years and been caught on both occasions — through to those who are just beginning to compile what will eventually be a long record. The history of the most convicted person in the sample indicates the alcoholic end of the spectrum (table 8). First convicted in 1972, this now unemployed, 37-year-old male had collected 11 priors before entering the sample with a BAC of 0.17% and charges of DUI and driving whilst still suspended for previous offences.

Associated with increased numbers of priors are average offences at higher levels (table 9). Many of the multiple offenders would appear to have alcohol-related problems that are immune to affect by current punishment and treatment systems. These offenders, it must be recalled, represent the caught and convicted. Behind them is a group of unknown size that has managed to avoid frequent detection.

ENTRY TO THE COURT SYSTEM

The time lag between arrest and conviction (table 10) indicates that most offenders are processed relatively quickly by the courts. The mean lag is 47 days but this is heavily influenced by a small number of cases with very long delays. Over a quarter of offenders were sentenced within 20 days and over a half in 40 days, emphasising the routine nature of drink driving cases. Longer delays usually reflect offenders who, commonly on advice from a solicitor, have sought adjournments.

Once charged, the next decision for many is whether to retain a solicitor. Petersen (1983), from a study in WA, indicates that about 25% of his sample hired a lawyer. He attributes the relatively low level of representation to the quantitative evidence of drink driving, seen by most offenders as unambiguous. Most, he claims, wish to minimise the stress and expense of contesting a case and to get it "over and done with" as soon as possible. In contrast, about two-thirds of the Tasmanian sample was represented (table 11). The proportion increases with number of priors and varies in a logical manner with occupational category (table 2). In this context, it is worth noting that legal aid is not available for

TABLE 8
Drink Driving Record of the Most Convicted Offender

Date	BAC (%)	Additional charges*
31.3.73	0.13	
26.1.74	0.22	DUI
1.2.74	0.15	DUI
10.11.74	0.15	–
17.4.77	0.17	DUI
23.12.78	0.17	–
9.6.79	0.16	DUS
10.10.82	0.10	DUS
28.5.83	>0.05	DUS
21.10.83	0.18	DUI, FYD, DUS, false name
23.4.85	0.15	DUI, false name

* DUS = Driving under suspension.

TABLE 9
Number of Prior Offences, Average BAC Level and High BACs

Number of priors	No. of persons	Mean BAC (%) of current offence	BAC > 0.14%	
			No . of offenders	%
None	571	0.11	89	15.5
One	234	0.12	53	22.6
Two	112	0.13	37	33.3
>Two	82	0.14	41	50.0

TABLE 10
Time Lag Between Arrest and Conviction

Number of days	Offenders	
	No.	%
< 0–19	229	26.9
20–39	243	28.6
40–59	157	18.4
60–79	80	9.4
80–99	64	7.5
100–149	55	6.5
150–199	12	1.4
200–299	10	1.2
> 300	1	0.1
Total	851	100.0

TABLE 11
Legal Representation and Prior Record

Number of priors	Number	Representation	
		No.	%
None	571	371	65.0
One	235	155	66.0
Two	112	81	72.3
>Two	82	67	81.7
Total	1000	674	67.4

defendants appearing on traffic charges unless there is a likelihood that the defendant will be jailed.

Amongst offenders, both first and recidivist, there is a belief that solicitors "know the system" and may be able to achieve a more favourable result by steering their client to an appropriate magistrate. The steering mechanism is discussed further below. One magisterial source has indicated that legal representation, by increasing court efficiency, warrants a small "discount". The reasoning is that in hiring a lawyer, offenders already incur a substantial cash outlay. Hence, any court fine might be reduced by a small amount. Whatever the reasoning, it is clear that drink driving offences generate substantial flows of money to the legal profession.

Client steering operates through adjournments which mean that a scheduled court appearance is postponed. Postponement may be by the magistrate or on the application of the offender or, more usually, a solicitor or the police. Adjournments can occur for many reasons but here only the number for each case is considered. Overall, 42.7% of the cases were adjournment free (table 12). However, less than half of first offenders were sentenced without adjournments whilst more than two-thirds of those with more than one prior had adjournments (table 12). Multiple offenders also had higher proportions of multiple adjournments. To a large extent, the delays caused by adjournments are responsible for the variations in arrest/conviction times.

Various factors lie behind decisions to request, or not request, adjournments. As noted above, some may wish to have their case finalised quickly. Adjournments may not be sought by some multiple offenders because they view their position with a sense of resignation. In some instances, adjournments are sought to prepare a case for an ancillary offence, particularly those of a non-routine nature.

Adjournments may be requested to gain appearance before a particular magistrate perceived to be either generally more "lenient" or more likely to treat specific categories of offender more leniently. There is ample evidence from the mainland to show that the sentencing styles of individual magistrates vary in identifiable ways (for example, Homel 1983). In Tasmania, there are statistically significant differences in the sentences handed down by the three benches of the Lower Court (Wood 1989b). Comment from people with regular and frequent contact with the courts (press and police) indicates that some individual magistrates are seen as "soft". Retaining a solicitor buys this knowledge and adjournments are the means by which clients may be

TABLE 12
Number of Adjournments by Number of Priors

No. of priors	Number of adjournments											
	None		1		2		3		>3		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0	275	48.2	186	32.6	75	13.1	23	4.0	12	2.1	571	100.0
1	93	39.6	82	34.9	32	13.6	17	7.2	11	4.7	235	100.0
2	35	31.3	30	26.8	26	23.2	12	10.7	9	8.0	112	100.0
>2	24	29.3	25	30.5	13	15.9	11	13.4	9	11.0	82	100.0
Total	427	42.7	323	32.3	146	14.6	63	6.3	41	4.1	1000	100.0

guided to a suitable appearance. It should be stressed that decisions about which offenders appear before each magistrate are made by the Clerk of the Court. Magistrates have no input.

In some instances, adjournments can be of value to an offender by delaying sentencing. This applies particularly with applications for restricted licences where the law stipulates that applicants must have a three-year period free from conviction for an alcohol-related driving offence. The period is measured not from arrest to arrest but from conviction to conviction, hence delays may be of benefit in some cases.

With current data, it is impossible to make more than inferences about the extent or targets of manoeuvring through adjournments. Certainly the number of drink driving cases heard by each magistrate varied markedly (table 13). One magistrate heard 23% of the cases, with most of the others handling between 11% and 15%. The apparently unequal division of hearings could reflect specialisation amongst the magistrates. Alternatively, it could be taken to illustrate steering of cases since, as is shown later, the magistrate who heard the most cases also made greatest use of the lightest penalties. More detail for specific sequences of adjournments would be necessary to explore this issue further.

THE OUTCOMES

Not surprisingly, the issue of most concern to offenders is the court decision. A variety of sentencing options is open to the courts. At the time of the survey, the main options were as follows:

(1) *Demerit Points (DPs).* These are ascribed to an offender's licence. Accumulation of nine DPs in three years leads to loss of licence for a specified period. DPs can also be awarded for other motoring offences.
(2) *Fines.* Occasionally all or part of a fine may be suspended on condition that no further breach of the law is committed within a set period.
(3) *Licence Disqualification.* Again, this may be delayed. When a person's livelihood is dependent on possession of a driver's licence, a restricted licence may be granted. This permits driving on certain routes at certain times.
(4) *Community Service Orders (CSOs).* A CSO requires an offender to work on a designated project for a specified number of hours. Only given with the consent of the offender, CSOs are often used in lieu of a fine.
(5) *Suspended Jail Sentence (SS).* A jail term suspended on condition that the offender commit no breach within a specified time.
(6) *Jail.*

Magistrates require all FYDs to attend a prescribed course that outlines the dangers of drinking and driving. On very rare occasions, they may also require attendance at an alcohol rehabilitation centre.

Details of the total penalties handed down for the sample are given in table 14. These bald figures indicate that fines and disqualifications, usually imposed in combination, are by far the most common penalty elements. DPs, at the time of the survey usually given with a fine to older offenders with low BACs and relatively clean records, were awarded in about 6% of cases. CSOs were allocated to about

TABLE 13
Number of Cases Heard by Each Magistrate

Magistrate	Cases
A	230
B	147
C	144
D	116
E	113
F	81
G	149
Total	1000

TABLE 14
Total, Range and Mean Penalties

Type of penalty and units	No. of offenders	Penalty			
		Total	Range		Mean
			Min.	Max.	
DPs (number)	59	229	1	4	3.9
Fine ($)*	896	150746	30	500	168.2
Disqual.(months)	942	10485	1	60	11.1
CSO (hours)	48	3853	25	180	80.3
SS (days)	64	2333	7	180	36.5
Jail (days)	33	2754	7	365	83.5
Restricted licences	69				

* Does not include court costs

5%. The more severe sanctions of SS and jail formed part of the penalty of 6. 4% and 3. 3% respectively.

The magnitude of the total sentences gives some indication of the effects that drink driving has on people's lives and on state services. This sample containing about 20% of the state's annual drink driving convictions, generated fines of over $150 000, cancelled driving licences for over 870 years and put people in jail for a combined total of 7.5 years. In addition to the direct effects for police, court, prison and probation staff, a drink driving conviction can also have social, familial and employment implications.

The sentencing options, as listed at the start of this section, can be seen in terms of an ascending severity ladder (Sparks 1971). To examine court decisions more closely, the package of penalties awarded to each offender was classified according to its most severe element. For example, a sentence involving DPs and a fine was classified as 'Fine', etc.

There is considerable public disquiet over perceived disparities in sentences handed down for apparently similar offences. A common magisterial response is that the public generally is unaware of all the facts associated with any particular case. In particular, the importance of prior records is stressed. The rest of this section examines sentences in terms of prior records and by magistrate.

Priors and Sentences

Cross tabulation of type of sentence by number of priors indicates that, generally, recidivists received more severe sentences than first offenders (table 15). Entries away from the broad diagonal generally reflect particular circumstances. For example, the two offenders with one prior for whom the most severe penalty element was a fine both had low BACs (< 0.09%) and a long arrest-free period (> 7 years). Conversely, of the three first offenders who were jailed, two had multiple ancillary offences including breach of bail and damaging police property.

TABLE 15
Type of Sentence and Prior Record

Number of priors	Most severe element in penalty				
	Fine	Disq.	CSOs	SS	Jail
0	50	502	11	5	3
1	2	211	8	10	4
2	0	72	15	19	6
> 2	0	23	11	27	21

Just as penalty severity increases with number of priors, so does the average quantity of each sentence element (table 16). An increase in the mean penalty from first offenders through to multiple recidivists is evident for all sentence elements except jail, where the numbers in most categories are very small.

An obvious inference is that magistrates use priors as a guide for penalty type and amount. Progression up the ladder of priors carries with it the strong likelihood of larger amounts of successively more severe penalties. It has to be stressed, however, that these are gross figures obtained by summing the decisions of all magistrates. The following section disaggregates sentences to the level of the individual magistrate.

TABLE 16
Mean Sentences by Prior Record

Number of priors	Number receiving DPs	Fine		Disq.		CSO		SS		Jail	
		No.	Mean ($)	No.	Mean (mths)	No.	Mean (hrs)	No.	Mean (days)	No.	Mean (days)
0	56	555	146.7	520	6.5	11	58.7	5	22.2	3	94.0
1	3	220	197.8	233	12.3	8	67.1	10	24.1	3	74.7
2	0	83	205.3	110	17.6	17	85.2	19	34.3	6	56.7
> 2	0	38	230.8	79	29.4	12	101.8	30	44.3	21	90.8

The Magistrate Factor

In terms of sentence types (table 17), all magistrates showed a strong preference for packages in which the most severe element was disqualification. This was almost always accompanied by a fine. Table 17 suggests that some magistrates use particular penalty types disproportionately. For example, more than two-thirds of the lightest penalty type (fine plus DPs) were handed down by just two of the magistrates (A and C). Similarly, E alone gave 40% of the CSO penalties whilst D, E and G appear under-represented for suspended sentences. Numbers in most of the cells of table 17 are too small to make stronger statements but there are sufficient indications of disparities to warrant more detailed examination of the major penalty type — that of a fine/disqualification combination.

Table 18 classifies these combinations in order of increasing severity from a disqualification of less than four months and a fine of less than $100 at the bottom of the scale through to disqualifications exceeding 18 months and all fines at the other extreme. These data relate only to offenders who received a fine/disqualification penalty and to the seven permanent magistrates. Seen in simple statistical terms, there is a highly significant difference between the magistrates (χ^2 = 223.8, d.f. = 60, p = <0.0001). Various under- and over-representations contribute to the difference. Major features are as follows:

TABLE 17
Individual Magistrate and Type of Sentence

Magistrate	Most severe element in penalty					
	Fine	Disq.	CSO	SS	Jail	Total
A	21	177	5	20	7	230
B	2	123	2	15	5	147
C	15	108	5	10	6	144
D	1	101	8	1	5	116
E	1	86	18	4	4	113
F	5	62	2	10	2	81
G	7	134	4	1	3	149
Other	0	17	1	0	2	20
Total	52	808	45	61	34	1000

– Magistrate A, already identified as having the largest number of cases and handing down the largest proportion of the lightest type of penalty (fine plus DPs), also shows the highest proportion of all the lightest fine/disqualification sentences. Over half of his sentences (51.4%) were in the three lowest categories, compared to less than a third for D, F and G.

– Magistrate G shows a heavy concentration in the range from 4 to 9 months. Over 70% of his sentences were in this range, compared to less than one-third for D.

TABLE 18
Fine/Disqualification Penalties by Magistrates

Fine/disqualification combination			Magistrate							
mths	+	$	A	B	C	D	E	F	G	Total
1–3	+	0–100	34	22	6	4	2	0	9	77
1–3	+	>100	20	8	11	17	10	10	5	81
4–6	+	0–150	37	32	25	12	25	9	30	170
4–6	+	> 150	7	8	5	8	14	12	25	79
7–9	+	0–150	13	3	7	9	2	4	21	59
7–9	+	> 150	7	8	10	4	12	9	20	70
10–12	+	0–200	20	21	21	9	4	2	6	83
10–12	+	> 200	5	6	6	5	7	9	5	43
13–18	+	0–200	20	3	0	15	4	1	2	45
13–18	+	> 200	9	7	8	7	4	2	6	43
> 18	+	all fines	5	5	8	11	4	4	5	42
Total			177	123	107	101	88	62	134	792

– Magistrates A, B, and C appear over-represented in the 10-12 months and more than $200 category.
– Almost one-third of D's sentences were in the highest three categories. None of the others exceeded 20% and one, G, scored less than 10%.

Whilst this evidence may be taken to indicate disparities in sentencing, it could be argued that the differences reflect the specific circumstances of the cases heard by each magistrate. Further insight can be obtained by selecting out offenders within specific categories. Table 19 provides data for males under 25, with no priors and a current BAC of less than 0.11%. Selection to meet these criteria produced 123 offenders; further breakdown by magistrates gives small numbers that only permit inferences. In all but a few cases, magistrates awarded a fine/disqualification penalty. The two who were jailed both had serious ancillary offences. In terms of fines, magistrate A again appears at the lenient end of the scale with the lowest average, minimum and maximum fines. His average fine was only 55% of that of magistrate G. The picture with regard to disqualification periods is less clear, though the highest average (D) exceeds the lowest (B) substantially.

It seems clear that individual magistrates in southern Tasmania differ substantially in their treatment of essentially similar cases. The existence of disparities is not surprising, given that the phenomenon has been widely reported elsewhere (for example, Homel 1983), but it has not previously been subject to detailed examination in Tasmania.

DISCUSSION

The public tends to view drink driving cases as clear cut. Guilt is rarely in question and a breathalyser reading gives incontrovertible evidence of the degree of transgression. The public expects that similar transgressions will be punished by the courts in a consistent fashion. Yet it is clear from the evidence presented here that sentencing disparities between benches in Tasmania (Wood, 1989b) are matched at the level of the individual magistrate. Who hears one's case can have a significant effect on the type and amount of sanction that is imposed.

It would seem that the current system of handling drink driving cases would benefit from review. Two alternatives, with many intermediates, can be outlined. One involves maintenance of the status quo. This implies that sentencing is and should be a highly individual affair. It accepts that magistrates can and should vary a sentence to suit the specific circumstances of both offender and offence.

TABLE 19
Sentences for Young, Male, First Offenders with Current BAC of Less than 0.11% by Magistrate

Penalty	Magistrate							
	A	B	C	D	E	F	G	Other
Type								
Fine	1	–	2	–	–	–	–	–
Disq.	20	27	14	13	12	10	17	3
CSO	–	–	–	–	1	–	–	–
SS	–	1	–	–	–	–	–	–
Jail	–	–	–	–	1	–	1	–
Total	21	28	16	13	14	10	18	3
Fine ($)								
average	96.2	102.7	119.4	154.2	162.3	167.8	174.7	156.7
number	21	27	16	13	13	9	18	3
minimum	30	50	60	75	100	100	75	110
maximum	150	250	235	250	240	350	260	200
Disqualification (months)								
average	5.0	3.8	4.6	7.1	4.1	5.7	5.9	4.0
number	20	28	14	14	14	10	18	3
minimum	1	2	1	2	2	2	3	3
maximum	15	12	12	15	9	18	9	6

However, the current system has aspects that may be viewed as disadvantageous and/or unjust. There is no doubt that it absorbs large public expenditures for what has become a routine charge. The current system encourages manoeuvring through adjournments which many regard as inequitable. A detailed knowledge of magistrates' sentencing styles, gained from court experience, is a major service that solicitors can offer to their clients. As has often been noted (for example, Hood 1972), sentencing disparities contribute to public disatisfaction with the courts and, by implication, the police.

Against this background, many have argued for revisions of the legal system particularly with reference to high frequency offences such as drink driving. Perhaps the most advocated alternative is for a "... network of prescribed sentences based on type of offence and offender's criminal record" (Ashworth 1970: 47). Homel's (1983) suggestion for sentencing drink drivers is that a two-way grid be drawn up in which one axis comprises BAC values (reflecting the seriousness of the current offence) and the other indicates previous drink driving and other motoring convictions (reflecting the blameworthiness of the offender). He advocates a range of penalties for each cell that is sufficiently broad to accommodate mitigating factors (such as unemployment) but much narrower than those currently evident in sentencing statistics.

This is not the place and the author is not the person to propose cut off points within such a grid. Difficult decisions on many questions would need to be made, including definitions of mitigating factors, procedures for handling ancillary offences, etc. Yet, properly researched and implemented, a sentencing system based on specified guidelines appears to have many advantages. It, presumably, would reduce community disquiet with the current system. It would give magistrates a firmer frame of reference. It might reduce public expenditure by increasing court efficiency. People with close contact with the system indicate that the "penalty" most disliked by many offenders is publication of their name and offence details in the press. Providing that this requirement is maintained, it may be worth exploring the option of automatic penalties that do not require court appearances for standard offences.

This research suggests that at least three other matters require consideration by the legislators. Firstly, if steering through adjournments is seen to be undesirable, an option may be to require that adjournments are granted only on condition that the defendant reappear before the initial magistrate; this, in turn, might require some revision of court procedures. Secondly, the legislation relating to the dating of arrest-free periods for restricted license applicants would benefit from review. Thirdly and most importantly, this study shows that recidivism is at a disturbingly high level in southern Tasmania. One implication is that current sanctions do not have a strong deterrent effect for many offenders. Additional procedures, not necessarily involving harsher penalties, need to be instituted for repeat offenders. An option may be to extend use of the P plate system requiring, say, people convicted more than once to carry P plates for a specified period.

Whether the current system is revised or not, one important issue remains to be discussed. There is a clear and urgent need for more information about court decisions. Such information would contribute to better public understanding of the system. It would also allow magistrates to compare standards. At present, there is no regular monitoring of court decisions. Such information could be used to identify and correct apparent discrepancies. It would also form a vital ingredient for any revision of the system.

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OCCURRENCE OF LOG-DWELLING INVERTEBRATES IN REGENERATION AND OLD-GROWTH WET SCLEROPHYLL FOREST IN SOUTHERN TASMANIA

by Robert J. Taylor

(with two tables and one text-figure)

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A list of coleopteran, large collembolan, centipede, millipede and molluscan species associated with rotting logs was compiled for an old-growth *Eucalyptus obliqua* wet sclerophyll forest and adjacent 19-year-old regeneration in southern Tasmania. A total of 67 species were found, 40 occurring in both areas, 53 in old-growth forest and 54 in the regenerated area. Of the species found in only one of the areas, nearly all occurred in one or two samples only, so no conclusion about their absence from the other area can be made. Two rarely collected species of beetles were recorded only in the old growth forest. Conservation of log-dwelling invertebrates in production forests is discussed.
Key Words: rotting logs, invertebrates, forestry, conservation.

INTRODUCTION

The development of strategies for conservation of invertebrates is impeded by the huge number of species, many undescribed, and the scant information on their distribution and ecology. Because of this, a strategy for conserving invertebrates by conservation of different vegetation types has been advocated (Marks 1972, New 1984). However, the distribution of many invertebrate species is known to be more restricted than that of the vegetation types in which they occur.

An analysis of the Tasmanian invertebrate fauna by Greenslade (1985) attempted a finer resolution of invertebrate habitats to aid in their conservation. Her analysis suggested that logs in a late stage of decay might be an important habitat for many species of invertebrates restricted to Tasmania. She reported that many entomologists had expressed concern about the effect of forest operations on logs as a habitat for invertebrates. They believed that charring of logs due to regeneration burning and drying out of these logs after the forest canopy was removed would make them unsuitable as a habitat for invertebrates.

A wide examination of the effects of logging on log-dwelling invertebrates would require a long and detailed study. This paper reports on the occurrence of selected groups of invertebrates associated with rotting logs at one wet sclerophyll site in southern Tasmania, where 19-year-old regeneration forest is adjacent to old-growth forest, and also on the results of a preliminary examination of the magnitude of differences between logged and unlogged areas.

STUDY AREA

The study area is situated along Edwards Road in the Huon River Valley approximately 500 m from the river (TASMAP 1:100 000, Huon 798 310). Aspect is westerly with gentle slopes. Elevation ranges from 110–130 m in the north of the site to 80–100 m in the south. Annual rainfall is in the range 1000–1250 mm with a broad winter maximum.

Both old-growth forest and regeneration occur alongside the road at this site. *Eucalyptus obliqua* dominates the canopy in both forests. The old-growth forest contains scattered large trees, some with a basal diameter greater than 2.5 m, which may be over 400 years old. Occasional groups of spars, 165–170 years old, occur together with dense pole stands originating from a wildfire in 1906. Two different understoreys are found. Rainforest is present in patches, comprising multi-age myrtle (*Nothofagus cunninghamii*) with *Anodopetalum biglandulosum*, *Anopterus glandulosus*, *Atherosperma moschatum*, *Eucryphia lucida* and *Phyllocladus asplenifolius*. Ferns include *Blechnum wattsii*, *Dicksonia antarctica*, *Histiopteris incisa* and *Polystichum proliferum*. Covering a smaller area than the rainforest understorey are patches of *Eucalyptus obliqua* poles over seedling myrtles (*N. cunninghamii*) with *Acacia*

dealbata, *A. melanoxylon*, *Coprosma quadrifida*, *Olearia argophylla*, *Pittosporum bicolor* and *Pomaderris apetala*.

A similarly variable understorey may have covered the regenerated block before logging, as small volumes of myrtle, blackwood and leatherwood were harvested. The area was logged from 1965–67 and regeneration burning was carried out in March 1969. Regeneration was largely natural but was heavily browsed, requiring additional "fill-in" sowing and planting. The regenerated block has been left untreated since spring 1971. Today the block carries *E. obliqua* regrowth under a few old-growth stags. Regrowth density varies greatly, and parts are poorly stocked with eucalypts. Under the poles the vegetation consists mainly of *Acacia dealbata*, *A. melanoxylon*, *A. verticillata* and *Pomaderris apetala*. Also present are *Dicksonia antarctica*, *Gahnia grandis*, *Monotoca glauca* and *Pteridium esculentum*.

Eucalypts make up the largest volume of rotting logs in both sites but wattle and rainforest logs are also present. All logs in the regeneration area were charred or partially burned in the regeneration fire and a high proportion of eucalpyt logs in the old-growth were charred — as standing trees — in the 1906 fire, which established the pole patches. Many of the rainforest logs in the old-growth block are deeply invaded by roots of the regrowth and as a result are relatively dry. Logs in the regeneration, on the other hand, are usually covered with bracken and leaf litter, and are generally wetter than similar-sized logs in the old-growth block.

METHODS

Fieldwork was carried out between 15 March and 7 April 1988. This period was extremely dry, with the summer rainfall at nearby Geeveston being the lowest on record. An area of 0.1–0.2 ha was searched per day, with old-growth and regeneration blocks being sampled on alternate days. All old, well-rotted logs and well-rotted portions of "recent" logs within the selected area were searched. Patches were 20–300 m from Edwards Road and were scattered through the forest with a bias toward deeper shade. The total area sampled was about 1.5 ha in each block.

Typically a 2 m long section was examined regardless of log diameter. In several cases, collections were made at a number of well-spaced points along each log and these were recorded as different samples. For each sample, log species (where recognisable) and approximate original diameter were noted. Different types of rot could be discerned. However, it was beyond the scope of the present study to detail the habitat preferences of individual species. Logs were broken open with a large chisel and carefully searched for invertebrates. Stumps, the undersides of logs lying on the ground and crevices on log tops and sides were also investigated. Only species of Mollusca (snails), Chilopoda (centipedes), Diplopoda (millipedes), Coleoptera (beetles) and large Collembola (springtails) were collected. These groups were selected as they were easily collected, morphological types were readily discernible in the field and taxonomists were available to identify the material (or at least to separate out different species). Specimens were removed by handpicking. Normally only one or two individuals of each species were taken. Each sample thus generated a list of species present.

Specimens were taken live from the study area for processing later the same day. Adult beetles were killed by freezing and pinned. Snails were drowned overnight in weak aqueous phenol, then transferred to 50% ethanol/5% glycerol. Beetle larvae and pupae were killed in 30% ethanol, myriapods and collembolans in 70% ethanol.

The numbers of logs of each tree species in the old-growth and regenerated sites are shown in table 1. Chi-square analysis was used to compare the frequency of occurrence of species in logs in the old-growth and the regenerated forest and to compare the use of logs from different tree species. Only those species which were found in ten or more logs were examined in these analyses.

RESULTS

Species Totals and Sampling Effort

Figure 1 shows the number of species collected as a function of the number of days spent sampling. The number of days is not directly related to sampling effort as two people collected on the first day in each area whereas on other days only one person was sampling. In the regeneration an asymptote had been reached by the end of the sampling; for the old growth only a very minor increase in number was occurring with extra sampling. Thus, it is likely that the sampling program had detected nearly all of the species which would have been found using the particular sampling methods employed for that particular time. The very dry conditions may have diminished

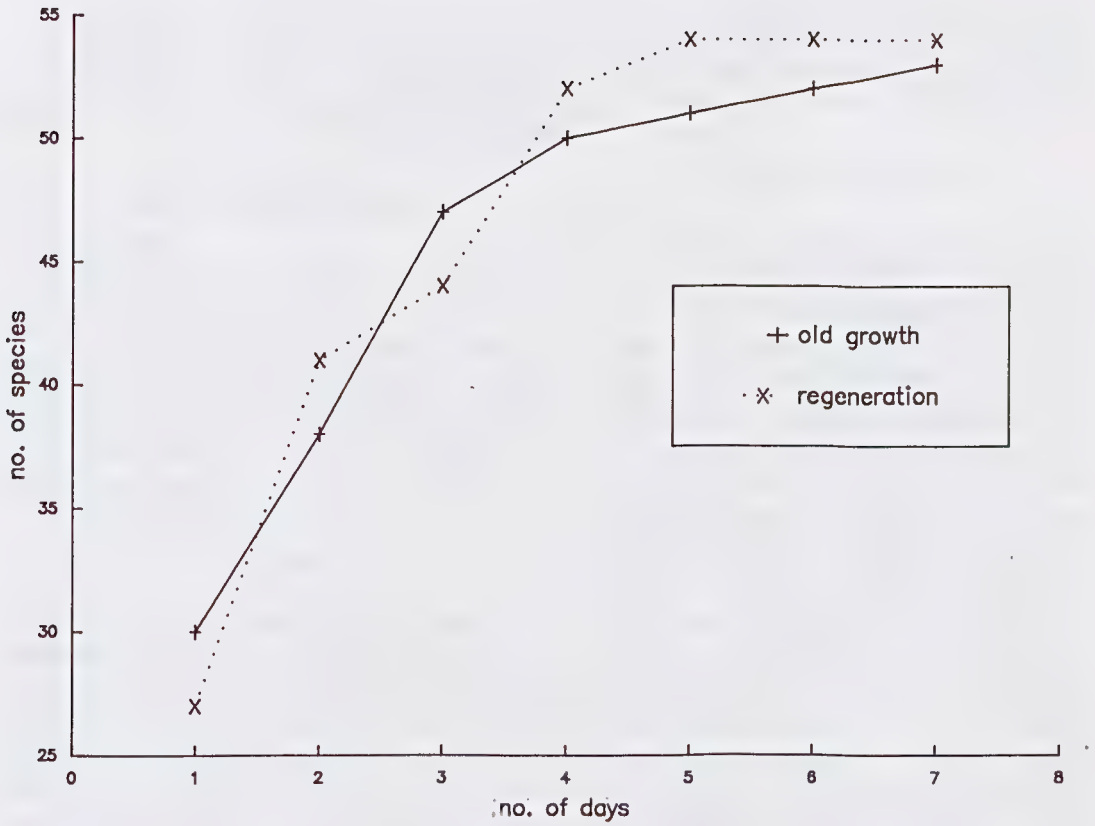

FIG. 1 — Relationship between the number of days spent sampling and number of species collected.

TABLE 1
Types of Logs Sampled in Regeneration and Old-Growth Areas

	Eucalypt	Myrtle	Sassafras	Wattle	Leatherwood	Unknown	Total
Old-growth (unlogged)	29	11	5	0	1	7	5
Regenerated (logged)	28	13	1	2	0	8	52
Total	57	24	6	2	1	15	105

species totals, due to some invertebrates leaving logs to shelter in soil crevices or moist leaf litter. Experience elsewhere suggests that under wetter conditions more specimens per sample would have been recovered (R. Mesibov, pers. comm.).

Comparison of Areas

Table 2 lists the "species" found and their frequencies of occurrence in logs in the two areas. One or two of the "species" categories may comprise several species (e.g. unidentified Tenebrionidae). Of the 67 species recognised, 53 occurred in old-growth forest and 54 in regeneration; 40 species occurred in both areas. Eighteen species occurred in numbers large enough to allow statistical analysis; all of these were found in both areas. The frequencies of occurrence of three centipede, three millipede, four beetle and two collembolan species did not differ significantly between the two areas. One snail, one centipede and one collembolan species were more frequent in logs sampled in the regenerated block, and one centipede and two millipede species were more frequent in the old-growth. One millipede and 12 beetle species occurred only in the old-growth area; 12 of these were found in only one or two samples; hence it cannot be concluded with any certainty that they were absent from the regeneration area. The one exception was the carabid beetle *Chlynus ater,* which was found in seven samples, but this occurred in the infrequently searched zone *under* rotting logs. Four snail, three millipede, six beetle and one collembolan species were found only in the regeneration; of these, the snail *Allocharopa legrandi* occurred in five samples and the millipede *Polydesmida* species D in three; all others occurred in only one or two logs.

Use of Tree Species

The 18 species occurring in ten or more samples were examined for any preferences shown for the species of log inhabited. Occurrences in non-eucalypt logs were grouped, due to small sample sizes. No significant differences were found between the frequency of occurrence of species in eucalypt and non-eucalypt logs and that expected on the basis of their frequency of being sampled.

Notes on the Species Found

Notes on the distribution and abundance of the snail (Smith & Kershaw 1981), beetle (P. McQuillan and D. Bashford, pers. comm.) and collembolan (Greenslade, in press) species are given in table 2.

Centipedes (Mesibov 1986)

Each of the six species collected has previously been recorded from the Huon district. All are widespread in Tasmania and can be locally abundant, especially as juveniles in leaf litter. The poor state of taxonomic and distributional knowledge makes it impossible to say whether any of the species are restricted to Tasmania within Australia. Centipedes apparently identical to *Cryptops megalopora*, *Henicops masulata* and *Zelanion antipodus* occur in New Zealand.

Millipedes

Tasmania's millipede fauna is very poorly known. Only a handful of species have been well described, and no distributions have yet been mapped. Assignment to higher taxa was based on descriptions and biogeographic information in Hoffman (1982). Only one of the 14 presumed species could be identified with confidence. *Lissodesmus modestus* has previously been collected near Russell Falls in Mount Field National Park and on Mount Wellington (Jeekel 1984).

DISCUSSION

A large proportion of species in the groups examined were present in both areas. Therefore, differences between the forest types in the fauna of this microhabitat are likely to be subtle and demand high levels of sampling intensity and replication. Consequently, the results of this study can only serve to guide future research and cannot be used to assess the effects of logging on the invertebrate groups examined. Given the similarity in species diversity between treatments, it is arguable that burning of the outside of a log does not cause it to become useless inside as a habitat for all invertebrates. The same conclusion has been reached by Mesibov (1988). Some species, however, may be adversely affected by burning of logs. The old-growth forest was burnt by a wildfire about 80 years ago. Thus, if a certain species was very sensitive to the effects of fire it could have also

TABLE 2
Occurrence of Invertebrates in Logs from Old-Growth and Regeneration Forest

Species	Old-growth (53 logs)	Regeneration (52 logs)	Difference between sites*	Notes
MOLLUSCA (live and dead shells)				
Caryodidae				
Caryodes dufresnii	6	2	–	Endemic, widespread
Charopidae				
Allocharopa legrandi	–	4	–	Endemic, known only from wet sclerophyll in S Tasmania
Mulathena fordei	–	1	–	Western and SE Tasmania
Roblinella gadensis	–	1	–	Endemic, previously only recorded from N and NW
Stenacapha hamiltoni	–	1	–	Endemic, widespread
Cystopeltidae				
Cystopelta petterdi	1	9	<0.05	Widespread
Helicarionidae				
Helicarion cuvieri	2	3	–	Endemic, widespread
Rhytididae				
Tasmaphena sinclairi	4	1	–	Endemic, widespread
CHILOPODA				
?Chilenophilidae				
Tasmanophilus opinatus	9	24	<0.001	
Zelanion antipodus	28	20	NS	
Cryptopidae				
Cryptops megalopora	4	1		
Cryptops sp.	15	3	<0.01	
Henicopidae				
"anopsobiine sp. 2"	14	8	NS	
Henicops maculata	4	8	NS	
DIPLOPODA				
Order Chordeumatida				
species A	5	4	–	
species B	2	2	–	
Order Polydesmida				
Lissodesmus modestus	24	13	NS	
Lissodesmus sp.	14	3	<0.01	
Asphalidesmus sp.	20	17	NS	
species A	8	6	NS	
species B	3	3	NS	
species C	2	6	–	
species D	–	3	–	
species E	–	2	–	
species F	–	1	–	
Order Polyzoniida				
species A	1	–	–	
Order Sphaerotheriida				
species A	32	4	<0.001	
Order Spirostreptida				
species A	2	6	–	

Species	Old-growth (53 logs)	Regeneration (52 logs)	Difference between sites*	Notes
COLEOPTERA				
Alleculidae				
species A	1	–	–	
Carabidae				
Chlynus ater	7	–	–	Widespread
Hypharpax sp.	1	–	–	Widespread, usually in open habitats such as grasslands
Notonomus sp.	2	1	–	Widespread in wet forests
Percosoma carenoides	2	–	–	Endemic, occurs in large patches of wet forest; largest Brosciniae in the world
Promecoderus tasmanicus	–	1	–	Endemic, wet sclerophyll forest in S Tasmania
trechine sp. A	1	2	–	Damp habitats
broscine sp. A (larvae)	2	1	–	
Unidentified larvae	1	1	–	
Cerambycidae				
Dorcadida biocularis	1	–	–	Endemic(?), widespread, occurs where dense litter
?Toxeutes arcuatus	–	1	–	Widespread in forests
Chrysomelidae				
Chrysophtharta agricola	–	1	–	Widespread in forests and woodlands
C. bimaculata	1	–	–	Widespread
Paropsis sp.	–	1	–	Genus widespread
Coccinellidae				
Cleobora mellyi	–	1	–	Widespread, predator of beetle eggs
Cucujidae				
Prostomis atkinsoni	4	9	NS	Widespread, found under bark on freshly fallen logs
Curculionidae				
Poropterus sp.	1	–	–	Widespread
cossonine sp.	1	1	–	Widespread group
Elateridae				
Crepidomenus sp.	1	–	–	Widespread
Elatichrosis trisulcata	12	15	NS	Wet forests
Lucanidae				
Lissotes cancroides	30	20	NS	Endemic, widespread in forests in S Tasmania
L. menalcas	1	–	–	Endemic, rare (approx. 20 specimens collected), wet forests in SE
Lycidae				
Metriorrhynchus sp.	4	4	–	Widespread
Oedemeridae				
species A (larvae)	2	3	–	
Staphylinidae				
species A	1	–	–	Widespread
species B	1	–	–	Widespread
Tenebrionidae				
Adelium abbreviatum	3	3	–	Wet forests
Coripera deplanata	4	2	–	Endemic(?), widespread in forests and woodlands

Species	Old-growth (53 logs)	Regeneration (52 logs)	Difference between sites*	Notes
Licinoma commoda	2	2	–	Widespread in forest and woodland
Meneristes australis	2	–	–	Wet forests
Unidentified (probably several species)	18	19	NS	
(Superfamily Scarabeoidea) species A (larvae)	–	1	–	
COLLEMBOLA				
Neanuridae				
Acanthanura dendyi	8	11	NS	Endemic, common in W and SW
Australonura wellingtonia	7	8	NS	Endemic, widely distributed
Megalanura tasmaniae	5	19	<0.01	Common in W and SW
?*Pseudachorutes* sp.	2	6	–	Unknown distribution
Uchidanurinae sp. 4	1	3	–	Specific identity uncertain
Uchidanurinae sp. 5	–	1	–	E distribution
Womersleymeria bicornis	4	2	–	Common in W and SW

* The significance of differences in species occurrences from logs in the two areas (NS = not significantly different; – = occurrence insufficient for analysis). Presence of beetle species was assessed from larvae, pupae and adults.

been eliminated from the old-growth forest. This raises the question as to what represents an experimental control. It is possible that there is no such thing as a pristine eucalypt forest with a completely intact complement of invertebrates which can serve as a baseline. For this reason, studies on the effects of logging are probably best carried out by comparing an area before logging and at varying time intervals after logging.

Logs were chosen as a habitat to be sampled because of their importance to certain groups of endemic species and because of comments on the possibility of regeneration burns affecting their suitability for invertebrates (Greenslade 1985). However, many of the species sampled will not be totally dependent on logs. Many may simply use logs for shelter or be capable of feeding in other microhabitats (such as litter) in the absence of logs. This will almost certainly be the case for snails, centipedes and millipedes. Old, decayed logs appear to be the preferred microhabitat of the collembolans sampled (Greenslade, in press). Coleopteran species sampled vary in their dependence on logs. The Lucanidae were used by Greenslade (1985) as an example of a log-dependent group containing many endemic species. Two species of lucanids (both endemic) were sampled in the present study. One occurred in both areas; for the other, known to be a rare species, one individual was found in the old-growth forest.

In the present study, two contiguous areas were selected as a control measure. It was assumed that the logged and old-growth areas had similar invertebrate faunas before logging occurred. However, after the first rotation of a large block of production forest is complete, it is possible that an individual coupe could become isolated from refuge areas. This may impede recolonisation of logged areas by those species with poor dispersal ability. Greenslade (1985) suggests that adversity-selected species will predominate in old rotting logs. One of the characteristics of these species is their poor dispersal ability; the great majority are endemic with restricted distributions (Greenslade 1985) and are thus species whose conservation is of concern. Retention of unlogged and unburnt strips of forest throughout production zones may reduce the likelihood of fire-sensitive species and species with poor dispersal ability being adversely affected by logging operations. The Forestry Commission is at present investigating the implementation of such a system of wildlife habitat strips (Taylor 1990) and has commenced research to investigate their value for fauna conservation.

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NOTES ON THE BIOGEOGRAPHY OF THE FREE-LIVING TERRESTRIAL INVERTEBRATE FAUNA OF MACQUARIE ISLAND WITH AN ANNOTATED CHECKLIST

by Penelope Greenslade

(with six tables and an appendix)

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The invertebrate fauna of Macquarie Island is examined and its size, composition, endemicity and biogeographical affinities are compared with those of other subantarctic islands. Its origins, dispersal mechanisms and adaptations are discussed and the effect on it of vertebrate predators considered. A checklist of the invertebrates known from Macquarie Island incorporating recent revisionary taxonomy is included as an appendix.
Key Words: Subantarctic, Insecta, Collembola, Mollusca, Oligochaeta, Arachnida, endemism.

INTRODUCTION

Prior to fieldwork carried out in the summer of 1986–87 by the author, the only large collection of terrestrial invertebrates from Macquarie Island was that of Watson (1967) who recorded 144 species, of which he believed 49 (34%) were endemic. A later work by Gressit (1970) added little further taxonomic information, although, for the first time, the invertebrate fauna of Macquarie Island was compared in detail with those of other subantarctic islands. Since then, revisionary taxonomy of a number of taxa has been published on the basis of more extensive material from throughout the subantarctic region (Selkirk *et al.* 1986). Using new information, a revised list has been compiled of species known from Macquarie Island (see appendix); this includes a number of new records. A trend observed, during its compilation, was a steady reduction in percentage endemism from the 1967 (Watson) and 1970 (Gressitt) figures. The level of endemism for Macquarie Island is now much lower than for other subantarctic islands and possible reasons for this are discussed here.

This new checklist excludes a number of the lower invertebrate taxa which are inadequately collected and does not cover freshwater species, of which there are very few. For example, although species of Protozoa (Watson 1967), Rotifera (Watson 1967), Turbellaria (Ball & Hay 1977), Nematoda (Bunt 1954), Copepoda (Hamond 1987) and Cladocera (Smirnov & Timms 1983) have been recorded from the island, most of these groups are still poorly known. All species so far recorded in them, apart from the Turbellaria, have widespread distributions. Neither are the Acari listed here in detail. Womersley (1937a) published some of the earliest records of mites and, although good collections are available from Macquarie Island, the faunas of adjacent territories have not been intensively studied, so that any list presented here would give a misleadingly elevated figure for the percentage endemism in this group (i.e. Wallwork 1973). Over 80 species of mites have been identified (D. Horning, pers. comm.), but the fauna certainly contains more than this and no revisionary work has been carried out for about 20 years. For this reason they have not been included in the discussion. "Adventitious" species, which include those which disperse from time to time to the island but are unable to establish permanent populations, i.e. naturalise, were listed by Watson (1967) and are not repeated here. The ectoparasitic Phthiraptera will be discussed in a later publication (D. Horning & R. Palma, pers. comm.).

Taxa are arranged as in *Insects of Australia* (CSIRO 1970) and Greenslade (1985). Full synonymies are not given for the species which occur widely outside Macquarie Island but most names mentioned in publications on Macquarie Island are included, except for those of Collembola which have recently been given by Greenslade &Wise (1986). Distribution records of each species are included and species are classified according to whether they have been introduced relatively recently, probably by humans, or are considered native to the island. The method used to determine to which category each species belongs has been described by Greenslade (1987a). Material collected in 1986–87 is deposited either in the South Australian Museum

(SAMA) (Collembola) or in the Australian National Insect Collection (ANIC) (all other invertebrates). Fieldwork was conducted in December 1986 and January 1987. Samples came from as many different habitats and sites on the island as possible and over 100 collections were made. Methods used included pitfall traps, funnel extraction of soil and leaf litter, sweeping and beating vegetation and searching under stones. A preliminary version of this checklist was published in Selkirk *et al.* (1990).

CHARACTERISTICS OF THE MACQUARIE ISLAND FAUNA

Size

So far as number of invertebrate species is concerned it is clear that the fauna is extremely small for a humid vegetated island of area 12 800 ha (120 km^2, 34 × 2.5–5 km). Only 76 resident species of terrestrial arthropods, molluscs and oligochaetes (excluding mites) (Table 1) are recorded despite considerable collecting effort. Although some Diptera species are yet to be identified, it is unlikely that this list will be increased by much.

Taking a single group, the Collembola, of which 31 species are listed, five were found only in the greenhouse among the main station buildings. In contrast, one can generally find 30 species of Collembola on a site of 10 m^2 in southern Australia. Even on Philip Island, a much smaller island (3 km^2) off the coast of Norfolk Island in the Tasman Sea, and at that time practically denuded of vegetation, 25 species have been collected (P. Greenslade), while The Snares, an undisturbed island group north of Auckland Island, similar in size to Philip Island, carries nearly 50 species of Collembola (P. Greenslade).

A comparison of the faunal size with that of other subantarctic islands is difficult because there are many variables in terms of latitude, area, climate, altitude, permanent snow cover and geological origin. (The term subantarctic islands is used here in its strict sense and includes only the Kerguelen, South Georgia, Heard, Prince Edward group (including Marion Island), Crozet and Macquarie Islands.) The most similar island to Macquarie Island appears to be Marion Island. Although being of volcanic origin, rather than raised seafloor as is Macquarie Island (Williamson 1988), it is of similar size, lies at a similar latitude (Table 3), is of a similar age (Bakker *et al.* 1971) and the invertebrate fauna is becoming well known (Crafford 1984, 1986, Crafford & Scholtz 1987, Crafford *et al.* 1986). Twenty-six insect species have been recorded from Marion Island compared with 31 from Macquarie Island (Table 4).

Returning to the Collembola, the size of the Macquarie Island fauna is of the same order of magnitude as those of the Kerguelen and Crozet Islands (Deharveng 1981) but if only native species are included, it is smaller (Table 5). Marion Island has a smaller fauna but it is probably undercollected while Heard Island, which has little ice-free area and then for only a short period in the summer, has an even smaller fauna (Greenslade 1986). Until Collembola have been collected from the other subantarctic islands as intensively as from Macquarie Island, further comment cannot be made about relative size of faunas.

Composition

The representation of higher taxa on Macquarie Island is very uneven. There are as many collembolan as insect species. Among the insects, the Diptera are the best represented group but only two families of Coleoptera are present and among the other large orders, there are few Hemiptera, Lepidoptera and Hymenoptera.

The composition of the insect fauna is similar to that of Marion Island in that five of the same orders of native insects occur. The main differences lie in that there are no Curculionidae, fewer Lepidoptera but more Staphylinidae and Diptera species on Macquarie Island (Table 4) compared with Marion Island.

The composition of collembolan faunas, so far as genera are concerned, is similar on all the subantarctic islands; genera such as *Cryptopygus* and *Tullbergia* are the most diverse and are characteristic of these faunas. The Kerguelen Islands have the largest and most varied collembolan fauna in terms of both genera and species (Deharveng 1981).

Endemism

A high level of endemism (34%), was recorded for Macquarie Island invertebrates by Watson (1967); when mites were excluded, this increased to about 40% (Table 2). Watson listed 20 endemic insects of which a number have now been recorded elsewhere or have been synonymised with other species. Gressitt (1970) stated there were 25 endemic species of insects out of a total of 40 (62%) including Collembola. There now appear to be only ten current endemics (c. 18% — two Collembola, six Diptera

TABLE 1
Terrestrial Invertebrates of Macquarie Island Excluding Mites

Order	Number of species probably introduced and now naturalised	Number of species introduced but not naturalised	Number of native and endemic species	Total number of species
Oligochaeta	1	–	7	8
Mollusca	1	–	3	4
Collembola	5	5	21	31
Psocoptera	–	–	1	1
Thysanoptera	–	–	1	1
Hemiptera	3	–	–	3
Diptera	2	1	12	15
Coleoptera	–	–	8	8
Lepidoptera	–	–	1	1
Hymenoptera	–	–	2	2
Araenae	–	–	2	2
	12	6	58	76 + 88 mites

TABLE 2
Numbers and Percentages of Endemic Species on Macquarie Island*

	Number of endemic species		Percentage of endemic species	
	1967 & 1970	1987	1967 & 1970	1987
Oligochaeta	1	2	17	33
Mollusca	1	0	25	0
Collembola	3(9)	2+2?†	33	6–12†
Diptera	10	6	66	31†
Thysanoptera	1	0	100	0
Psocoptera	1	0	100	0
Hemiptera	0	0	0	0
Coleoptera	1	0	12	0†
Hymenoptera	1+1?	0	100	0
Lepidoptera	1	0	100	0
Araneae		0	0	0
Mollusca		0	0	0
Endemic species	20+1?	10+2?	~40%	~17%
Total species	51	76		

* Recorded by Watson (1967) and Gressitt (1970), and those currently known.
† Taxonomic studies not yet complete.

TABLE 3
Comparison of Physical Characteristics of Marion and Macquarie Islands*

	Marion Island	Macquarie Island
Area (km^2)	290	118
Permanent ice cover (ha)	50	
Area below 500 m (ha)	150	118
Latitude (°C)	46.9	54.6
Temperature of the coldest month (°C)	33	
Distance from nearest mainland (km)	1900	990
Distance from nearest land (km)	1900	610
Distance from nearest land westward within 10° latitude (km)	3270	5490
Mean annual temperature (°C)	5.1	5.0
Mean annual precipitation (mm)	2575	903
Age (years)	~1–2 million BP	est. >100 000 to <1 million BP
Number of species of vascular plants	22	45

* From Abbott (1974).

TABLE 4
Comparison of Number of Insect Species Known from the Prince Edward Group* and Macquarie Island

	Prince Edward Group†			Macquarie Island		
	Native and endemic species	% endemic species (nos)	Naturalised aliens	Native and endemic species	% endemic species (nos)	Naturalised aliens
Insects						
Psocoptera	1	0	0	1	0	0
Thysanoptera	0	0	1	1	0	0
Hemiptera	0	0	3	0	0	3
Coleoptera	7	43(3)	0	8	0	0
Diptera	5	49(2)	4	4?	46(6)(+1?)	2
Lepidoptera	3	33(1)	1	1	0	0
Hymenoptera	1	0	0	2	0	0
Totals	17	35(6)	9	26	23(6)	5
Collembola	13	15(2)	0	21	10(2)+2?	10

* Includes Marion Island
† From Crafford *et al.* (1986)

TABLE 5
Comparison of Collembolan Faunas of Subantarctic Islands

Island	Total number of native and endemic species	Number of endemic species	% endemic species	Number in common with Macquarie Island	%
Macquarie	21	2(+2)*	10(?20)	–	–
Heard	8	1	12	7	88
Marion	13	2	13	7(+2)*	54
Kerguelen	30	9(+2)*	30	10(+2)*	33
Crozet	28	8	29	6(+3)*	21

* Species of *Sminthurunus* and *Megalothorax* not yet fully determined.

TABLE 6
Biogeographic Affinities of the Macquarie Island Terrestrial Invertebrate Fauna

Taxon	Number of species	Cosmopolitan	Western subantarctic islands	New Zealand subantarctic islands	Unknown
Oligochaeta	8	1	5	–	2
Mollusca	4	1	–	1	2
Collembola	31	10	16	4	1
Insecta					
Psocoptera	1	–	–	1	–
Thysanoptera	1	–	–	1	–
Heteroptera	3	3	–	–	–
Diptera	15	3	2	5	5
Hymenoptera	2	–	–	1	1
Coleoptera	8	–	–	5	3
Lepidoptera	1	–	–	1	–
Araneae	2	–	1	1	–
Totals	76	18	24	20	14

and two Oligochaeta) with a few others doubtfully endemic (e.g. other Diptera). The Macquarie Island population of *Eudonia* (Lepidoptera) is distinct probably at less than subspecific level (J. Dugdale, pers. comm.).

This level of endemism is lower than that of Marion Island and the neighbouring Prince Edward Island for which six (35%) of the 17 native insect species, excluding Collembola, are endemic (Table 4). The other nine species are classed as naturalised aliens by Crafford *et al.* (1986). Treated separately, Marion Island and Prince Edward Island each have only one species not occurring on the other. The two islands represent the summits of two extinct volcanoes and are separated by only 20 km. Although Prince Edward Island is only one-seventh the size of Marion Island, they have practically identical faunas. Crafford gives the percentage of insect endemics (excluding Collembola) for Kerguelen, Heard and Crozet Islands of 27, 11 and 67 respectively. Only that of Heard Island, with a small fauna of nine species and one endemic, is less than that of Macquarie Island.

As far as collembolan faunas are concerned, Macquarie Island has a similar level of endemism to Marion Island, which is certainly under-collected,

but less than half that of Kerguelen and Crozet Islands (table 5). On the whole the Collembola can be taken as characteristic of the invertebrate fauna of Macquarie Island because they are relatively well known and collected and recent revisions are available for the faunas of the Kerguelen group and Heard Island, as well as for Macquarie Island. Also fairly good information is available for South Georgia, Campbell and Auckland Islands. Therefore, estimates of endemism and species relationships should be relatively reliable for this group. In the past, endemism has been calculated from imperfectly known taxa, which can lead to bias (see Watson 1967, Gressit 1970, Wallwork 1973, Abbott 1974). Collembola represent a high proportion (40%) of the total number of arthropods, molluscs and oligochaetes excluding mites, from Macquarie Island. The trend in successive calculations of the level of endemism has been towards lowering this figure as faunas become better known taxonomically (table 2).

Affinities

The taxonomic relationships of the fauna are given in table 6 where the species are grouped as either cosmopolitan or having eastern, western or unknown affinities. The classification is based on where the species or its closest relative occurs outside Macquarie Island. From the totals in table 6, it appears that the faunal affinities and hence origins lie approximately equally with the western and with the New Zealand subantarctic islands. As far as the insects are concerned, relationships are largely with New Zealand. However, the Collembola and the Oligochaeta show affinities to the west, i.e. with subantarctic islands on the opposite side of the antarctic continent. These taxa are more closely associated with the soil than the insects which live for the most part above the soil and litter surface, for at least part of their life cycle, and tend to be more vagile.

From table 6 it can be seen that only four collembolan species have affinities with New Zealand. These are all epigaeic, surface, leaf litter or above ground species *(L.mawsoni, I.turbotti, P.davidi, K.banzare)*, while the species with taxonomic affinities to the west, i.e. with other subantarctic islands, live lower in the profile, mostly in humus and soil. A higher proportion of these epigaeic species are predominantly restricted to coastal habitats (three out of four species). Alternatively, two species found almost exclusively on the plateau are both soil dwelling and have affinities with subantarctic islands to the west *(F. simplex, I. (Pseudosorensia) atlantica)*. In table 5 the relationships of Macquarie Island Collembola with those of other subantarctic islands is examined in more detail. The Macquarie Island fauna appears most similar to that of Heard Island, but this is probably because the small fauna of the latter island consists almost entirely of widespread subantarctic species.

DISCUSSION

When comparing the Macquarie Island fauna with the fauna of the other subantarctic islands, the many variables operating, such as latitude, size, altitude, distance from major land masses, climate, ice free areas etc., have to be considered. Certain common features of their faunas do emerge in spite of those differences and these have been noted by earlier authors (Gressitt 1961, 1962, 1964, 1970, Crafford *et al.* 1986). All subantarctic islands have small faunas with a disharmonic composition of higher taxa (Carlquist 1974). The same characteristics have been noted for antarctic faunas (Block 1985). However, the level of endemism varies, and on Macquarie Island, from which only one endemic plant is known (P. Selkirk, pers. comm.), the level of endemism appears to be lower than might be expected, given that the island is fairly large, is well vegetated and has an equable climate. Taking into account the trend towards a lower level of endemism with increasing knowledge of the taxonomic affinities of the fauna, it is possible that it may fall even further. One explanation suggests that the ecosystems on the island may be young (Selkirk *et al.* 1983, Selkirk *et al.* 1988), having been formed on a raised part of oceanic crust, most of which emerged above sea level perhaps only during the Pleistocene (Williamson 1988), rather than being a relict of an older, once larger land mass. Gressitt earlier suggested a recent origin for the Macquarie Island fauna based on the few wingless insect species that occur there, although he believed the island itself had formerly been part of a larger land mass (Gressitt 1962).

The lack of correlation in the Subantarctic between island area and number of species has been commented on already (Gressitt 1970, Crafford *et al.* 1986) and it has been said that these faunas provide no support for MacArthur & Wilson's (1967) equilibrium theory of island biogeography. Abbott (1974) attempted to find a relationship between the number of insect species (excluding Collembola) occurring on 19 subantarctic and other isolated oceanic islands and their physical and

biological characteristics. These included area, distance from source area, nearest land to the west, elevation, minimum and maximum temperatures, rainfall, and numbers of plant and bird species. He found no significant correlation between numbers of insect species or any of the measures of isolation, area, latitude or climate. Significant correlations were found between number of insect species and temperature, and he also found that the number of vascular plants can be used to predict the number of insect species. This may simply reflect that plants and insects have similar capacities for dispersal to distant land masses, rather than a direct dependence of insects on plants. Abbott's (1974) comment that area is of minor importance in explaining variation in number of insect species on isolated islands may be due to the fact that when long distance dispersal is involved, the relative ages of the islands are likely to be a more important factor. This does not reduce the validity of the MacArthur & Wilson (1967) model since these authors stressed that a time factor was involved in determining faunal size as an equilibrium between immigration and extinction.

It is not surprising that the relationship of much of the insect fauna of Macquarie Island is with New Zealand, despite the prevailing wind being from the west. New Zealand and its islands are only 640 km distant and there are occasional winds from the northeast (Adamson *et al.* 1988). A parallel distribution pattern is seen with the fish, where the majority of benthic species have affinities with the western subantarctic region while most pelagic species have distributions in more northerly temperate waters (Williams 1988). The marine and littoral invertebrates, however, show a different pattern. Relationships of shallow water and littoral species are with the circum-subantarctic zone whilst more benthic species show northern or cosmopolitan affinities (Dawson 1988). Although the Rhodacaridae (Acari) of Macquarie Island (Lee & Hunter 1974) seem to have colonised from New Zealand, other invertebrate taxa, more closely tied to the soil, appear to have originated from the west.

The theory of plate tectonics has contributed to a transformation of our understanding of biogeography and the origins of island faunas. There are still problems, however, regarding islands of recent origin, such as Macquarie Island. Danks (1981) commented that zoogeographical speculation easily outstrips the evidence, and much has been written concerning means of dispersal to isolated islands, particularly of brachypterous species. The ability of these species to disperse is probably underestimated because they can have resistant and/or dormant life stages. A combination of four factors can explain faunal composition; distance from source area, ease of dispersal of propagule, time and availability of suitable habitat at destination. Limitations of area are not relevant to Macquarie Island at present, because, as has been pointed out by Block (1985) for the Antarctic (and the Subantarctic is similar), invertebrate faunas of subantarctic islands tend to be unsaturated, and habitats contain vacant niches. This is supported by the speed at which introduced species colonise and spread on Macquarie Island (Greenslade & Wise 1984, 1986). Migration studies indicate that there is a continuous rain of propagules of easily dispersed insects on any area such as Macquarie Island. They can be transported by wind (Close *et al.* 1978, Washburn & Washburn 1984, Farrow 1984, Pierrehumbert *et al.* 1985, Benninghoff & Benninghoff 1985, Duckhouse 1985, Edwards 1986), drift in currents (Lee 1968, Cheng & Birch 1978) or be brought by man or other animals (Lawrence 1971). Birds have been reported transporting free-living invertebrates (Jamieson 1968) and on Macquarie Island fruits of *Acaena magellanica* were observed attached to the breast feathers of a skua (P. Greenslade). The fruits can hold large numbers of aphids *(Myzus ascallonicus)* and occasional other arthropods (P. Greenslade).

Brachyptery is a trait for which a number of different ecological explanations have been offered (Greenslade 1965). Crafford *et al.* (1986) reviewed the literature and suggested, as did Smithers (1972), that it is paedomorphic in origin. It is known that juvenile hormone prolongs its activity at low temperatures (Wigglesworth 1952) and photoperiod length affects the activity of the corpora allata. The possible physiological causes of brachyptery are discussed by Matsuda (1976). On Macquarie Island less than half the beetles (3), less than one quarter of the flies (3), no moths and the wasp are brachypterous (total 35%). Of the brachypterous species, only the two Diptera are at present considered to be endemic. Alternatively, in the Prince Edward Island group which includes Marion Island, 15 of the 16 native species are brachypterous, and the percentage of flightless insects is 90 or more in the Kerguelen, Crozet, and Heard Islands. These figures are over three times that of Macquarie Island, which is probably another indication of the relatively recent arrival of the fauna. Brachyptery is characteristic of species found in environments where adversity or A selection is operating (Greenslade 1983). Wing abnormalities are a common feature of inbred populations both in culture and in nature. However, the mechanism by which brachyptery is achieved is not relevant here

and it is certainly in part a parsimonious response (Downes' 1964 economy of effort) to low biological complexity.

The products of A selection tend to have low reproductive rates, poor dispersal mechanisms, low fecundity and rates of increase, long length of life, late maturity, and slow development (Greenslade 1983). There is selection for parthenogenesis to a variable extent and it has been suggested (Crafford & Scholtz 1986) that parthenogenetic species are preadapted for subantarctic habitats. Parthenogenesis can also be selected for in habitiats in which *r*-selection occurs. The Macquarie Island fauna carries a high proportion of species which are apparently *r*-selected and which have probably been introduced relatively recently (marked ‡ in check list in the appendix). Some of these species are parthenogenetic, for instance all the Psychodidae and Chironomidae. Edwards & Usher (1985) have pointed out that antarctic species have a need for flexible life histories, usually a characteristic of A selection.

The composition of the fauna of Macquarie Island is unlike any other subantarctic island in the lack of curculionids as noted by Gressitt (1970). For instance, on all other subantarctic islands except South Georgia several species of curculionids occur and they are often endemic. Three of the five curculionids in the Marion group of islands are endemic species and one of four on Heard Island (Kuschel 1970). A suitable curculionid habitat of *Poa* roots in deep peat (a habitat in the Falkland Islands described by Lewis Smith & Prince (1985) as a "remarkable" environment) is present in abundance on Macquarie Island. Possible reasons for their absence are the combination of poor dispersal ability and the island's youth. Alternatively, Crafford & Scholtz (1987) suggested that the absence of a *Pringleophaga* species (Lepidoptera) on Marion Island, despite its presence on Prince Edward Island and the Kerguelens, could be the result of predation by introduced mice. Mice as well as the insectivorous weka have been present on Macquarie Island since the 19th century and it is possible they have had some effect on the insect fauna but they are unlikely to have caused extinction of any species, particularly weevils.

The diet of *Mus musculus* on Macquarie Island consists mainly of insects (Copson 1986); arachnids, lepidopteran larvae and Diptera have been found in mouse stomachs in that order of abundance. However, even where curculionids are abundant on subantarctic islands they are not eaten to any great extent by mice (Gleeson & van Rensburg 1982) as the larvae of these insects live in soil and are therefore largely unavailable to surface-feeding predators. The diet of the weka, which colonised coastal sites only and is now probably eliminated from Macquarie Island, was studied by Brothers & Skira (1984). Invertebrates were found in nearly all stomach contents examined and included kelp flies, spiders, and lepidopteran larvae. In addition, the extent to which the type and abundance of invertebrates has been affected by native insectivorous birds on the island is unknown but could have been significant.

As the only remaining indigenous land animals of Macquarie Island (two terrestrial bird species became extinct before1900), invertebrates are significant members of the biota and are key elements in food webs (Burger 1985). Aboveground herbivory is low on subantarctic islands (Crafford *et al.* 1986), and so the soil and litter fauna is more important in nutrient cycling here than in more temperate climates. With the possibility of climatic amelioration (Adamson *et al.* 1988), it might be expected that the rate of colonisation by exotic species will increase. Taking the Collembola as an example, a third of the species now found on the island have almost certainly been relatively recently introduced by man and half of these have become naturalised. Some changes might be expected in trophic roles and in the cycling of organic matter (both on the island and between the terrestrial and marine ecosystems by means of marine invertebrates) as a result of changes in the decomposer organisms present.

EPILOGUE

"The ward-room is the battle field of more scientific thrills. The dining-table resembles a section of richly verdured South Georgian terrain. Sir Ernest Shackleton, Jock Wordie, Robbie Clark, Hussey, Dr Macklin and one or two helpers, armed with forceps and magnifying lenses, bend over a heterogenous profusion of grasses, mosses, lichens, azorellas, etc. They are searching the tangled mass, blade by blade and leaf by leaf, for tiny springtails, diminutive spiders, beetles, slaters, and other lowly insects. Though I sympathize with the scientists, I am afraid I have not the patience to enthuse over these microscopical 'bug hunts'. Evidently they stimulate in the scientific mind some highly specialized emotion which I lack. However, I admire the zeal and indefatigable patience of these learned men." (Hurley 1979.)

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APPENDIX
Annotated Checklist of Free-living Terrestrial Invertebrates of Macquarie Island

* new record (localities given)
† endemic species
\# species recorded earlier from Macquarie Island but probably misidentified
¶ native (indigenous)
‡ introduced and naturalised
§ introduced and not naturalised

OLIGOCHAETA

MEGASCOLECIDAE

Microscolex macquariensis (Beddard 1896) †

Considered to be endemic to Macquarie Island (Lee 1959, 1968) and, according to Lee, most closely related to species from South Georgia and the Kerguelen Islands, but also close to a species in Campbell Island. Sims (1971) states that this species may only be a geographical race and not a full species.

LUMBRICIDAE

Bimastus tenuis (Eisen 1874)

Recorded by Lee (1968) and also known from Kerguelen and Heard Islands; a cosmopolitan species.

TUBIFICIDAE

Macquaridrilus bennettae Jamieson 1968 †

An endemic species of a monotypic genus. It is considered to be an ancestral form of obscure relationships and may have reached the island only recently (Jamieson 1968).

ENCHYTRAEIDAE

Enchytraeus albidus Henle 1837 ¶

Also known from the Kerguelen and Crozet Islands; recorded from Macquarie Island by Lee (1968) from a determination by L. Cernosvitov; occupying marine, limnic and terrestrial habitats. One of the commonest species in the family.

Pachydrilus macquariensis (Benham 1915) = *Lumbricillus macquariensis* Benham 1915 ¶

Also known from Heard Island. Recorded by Lee (1968) from a determination by L. Cenosvitov.

Pachydrilus maximus Michaelsen 1900 ¶

Also known from Heard Island and the Kerguelens. Recorded by Lee (1968) from a determination by L. Cernosvitov.

Pachydrilus werthi (Michaelsen 1905) = *Lumbricillus werthi* (Michaelsen 1905) ¶

Marionina antipodum (Benham 1905) ¶

MOLLUSCA

ATHORACOPHORIDAE

Reflectopallium martensi (Suter 1909) ¶ = *Athoracophorus (Amphiconophora) martensi* Suter 1909

Also occurs on Auckland Island. An indigenous species according to Watson (1967) but not recorded by Dell (1964). Burton (1963) erected the genus *Reflectopallium* and gave the Auckland Islands as the locality but subsequently mentioned a Macquarie Island locality (p. 73). In a later publication (Burton 1980) he added a further discussion of the species.

Pseudaneitea huttoni (Suter 1909) ¶ = *Athoracophorus (Pseudaneitea) huttoni* Suter 1909

Also occurs on The Snares. An indigenous species according to Watson (1967) but not recorded by Dell (1964). Burton (1963) did not give a Macquarie Island locality.

LIMACIDAE

Deroceras reticularis Müller 1774 ‡ = *Agriolimax agrestis* Linné *sensu* Hedley 1916

According to Hedley (1916), this European slug has been introduced and was first found around sealers' huts at Lusitania Bay. It is the commonest British slug and has a cosmopolitan distribution. Dell (1964) commented that it is now well established.

PUNCTIDAE

Phrixgnathus hamiltoni Suter 1896 ¶ = *Laoma (Phrixgnathus) hamiltoni* Suter 1896 = *Phrixgnathus hamiltoni* Hedley 1916? = *Laoma campbellica* Hamilton 1894 (misidentification)

According to Hedley (1916), this snail was the "southernmost in the world", but molluscs have now been recorded from terrestrial habitats on Heard, Possession, the Kerguelen, Marion, and South Georgia (Cumberland Bay East) Islands (Block 1984). Dell (1964) considered that this species is very close to an inadequately described species from Campbell Island, *Phrixgnathus cambellica*

(Filhol). Affinities of this species are definitely with New Zealand. F. Climo (pers. comm.) considers the Campbell, Auckland and Macquarie specimens to be conspecific although the species is morphologically variable.

TARDIGRADA

MACROBIOTIDAE

Pseudobiotus augusti (Murray 1907) ¶?

Probably a cosmopolitan species (Ramazzoti & Maucci 1983). Several other tardigrade species have been collected, perhaps as many as 40, but records have not yet been published. Nearly all appear to be widely distributed (D. Horning, pers. comm.).

ARTHROPODA

COLLEMBOLA

HYPOGASTRURIDAE

Hypogastrura (Hypogastrura) purpurescens (Lubbock 1868) ‡

Hypogastrura (Hypogastrura) viatica (Tullberg 1872) ‡

Hypogastrura (Ceratophysella) denticulata (Bagnall 1941) ‡

These three species are cosmopolitan and *H. purpurescens* and *H. denticulata* have probably been introduced recently (Greenslade & Wise 1984, 1986).

NEANURIDAE

Friesea tilbrooki Wise 1970 ¶ = *Friesea viennei* Deharveng 1981

Also known from Heard Island and Bouvetoya (Greenslade 1986, Greenslade & Wise 1986).

Friesea simplex Cassagnau & Rapoport 1962 ¶*;

Otherwise only known from the Tucuman district of Patagonia (Deharveng 1981). Locality: Plateau, in Azorella, 1986–87.

ONYCHIURIDAE

Tullbergia bisetosa Börner 1902 ¶

Tullbergia templei Wise 1967 ¶

Both these species are widespread in the Subantarctic (Greenslade 1986, Greenslade & Wise 1986).

Mesaphorura sp. *krausbaueri* group Börner 1901 §

An introduced European species which has only been found so far in the Macquarie Island station greenhouse; also known from Australia (Greenslade 1987b).

Protaphorura fimatus (Gisin 1952) §

Only recorded so far in the greenhouse (Greenslade 1987b); also known from Europe in compost. Another species in the genus was recorded as introduced to Deception Island (Greenslade & Wise 1984).

ISOTOMIDAE

Archisotoma brucei (Carpenter 1907) *sensu* Poinsot 1965 ¶*

Also known from Auckland Island (Salmon, identification not confirmed) and Signy Island (new record, P. Greenslade). Locality: Hasselborough Bay, Buckles Bay.

Isotoma (Parisotoma) insularis Deharveng 1981 ¶?

Also from Crozet Island. The Macquarie Island specimens have some differences from those from Crozet Island and may subsequently prove to be a different species.

Isotoma (Folsomotoma) punctata Wahlgren 1902 ¶

Widespread in the Subantarctic region. Not on Auckland or Campbell Islands, where a different *Folsomotoma* species occurs.

Isotoma (Desoria) tigrina Nicolet 1842 ‡

An introduced European species also known from Australia.

Isotoma (Pseudosorensia) sp. cf. *atlantica* (Wise 1970) †

This species may be new and possibly endemic; further taxonomic studies are required.

Cryptopygus antarcticus antarcticus Willem 1901 ¶

A common species of the Antarctic and Subantarctic.

Cryptopygus dubius Deharveng 1981 ¶

Also known from Marion Island.

Cryptopygus caecus Wahlgren 1900 ¶

A very widespread species and native to the Southern Hemisphere.

Cryptopygus lawrencei Deharveng 1981 ¶

Also known from Kerguelen Island.

Cryptopygus tricuspis Enderlein 1909 ¶

Widespread in the Subantarctic (Greenslade 1986, Greenslade & Wise 1986).

Proisotoma minuta (Tullberg 1871) §*

Only known from the station greenhouse, but a common widespread species with numerous records from Australia in disturbed habitats.

Isotoma turbotti Salmon 1949 ¶?*

This species was described from Auckland Island. Locality: Green Gorge.

ENTOMOBRYIDAE

Lepidobrya mawsoni (Tillyard 1920) = * *Lepidobrya aurantica* Salmon 1949 *syn. nov.* ¶ (Taxonomic justification for synonymies to be published — P. Greenslade, in prep.)

Also known from Campbell and Auckland Islands. This species was previously thought to be endemic to Macquarie (Womersley 1937c).

Lepidocyrtus sp. *lignorum* group nr. *violaceus* Geoffroy 1762 ‡*

Previously recorded under the names of *Lepidocyrtus cyaneus cinereus* Folsom 1924 and *Lepidosira terra-ereginae* Ellis & Bellinger 1973 (Greenslade & Wise 1986). These identifications were made by Salmon (Watson 1967) based on few and poor specimens. More material is available now and all Macquarie Island Lepidocyrtini collected belong to the same species. According to W. Hüther (pers. comm.) the specimens are dissimilar to all forms from Europe so far examined by him.

SMINTHURIDAE

Sminthurides sp. *malmgreni* (Tullberg 1876) group §*

Only known from the greenhouse, and belonging to a species group recorded from southern South Australia, close to a species from Kangaroo Island.

Polykatianna davidi (Tilyard 1920) ¶ = *Polykatianna gressitti* (Salmon 1964) *syn. nov.* = *Polykatianna litorea* Salmon 1943 *syn. nov.* = *Polykatianna litorea luteaterga* Salmon 1943 *syn. nov.* (Taxonomic justification for synonymies to be published — P. Greenslade, in prep.)

This species, previously thought to be endemic to Macquarie Island (Womersley 1937c), is now known from Campbell Island, Auckland Island and mainland New Zealand.

Sminthurinus kerguelenensis sensu Salmon 1964 #

Also known from the Kerguelens. This species was identified from Macquarie Island by Salmon (1964) from an immature specimen but was probably a mis-identification.

?*Sminthurinus* sp. cf. *terrestris* Womersley 1931 ¶?†

Collected sporadically from coastal sites.

Sminthurinus quadrimaculatus (Ryder 1879) §

Only known from the greenhouse (Greenslade 1987b) and previously only recorded from North America.

Sminthurinus sp. cf. *tuberculatus* Delamare & Rapoport 1963 ¶*

Also known from southern South America. Various collections from the Plateau and from coastal sites.

Sminthurinus sp. nr *granulosus* Enderlein 1909 ¶?*

Also recorded from the Crozet, Kerguelen and Marion Islands (De Harveng 1981). Only immature specimens are available so a definite identification cannot be made. Locality: *Poa* on plateau, above Hasselborough Bay c. 250 m.

Katianna banzare Salmon 1964 †

At present this species is only known from Macquarie Island and may be endemic, although some unidentified immature *Katianna* species have been seen from Campbell Island and are known from the Kerguelens and The Snares.

NEELIDAE

Megalothorax sp. or spp. ¶?

Not identified as the genus is poorly known worldwide.

INSECTA

PSOCOPTERA: PHILOTARSIDAE

Austropsocus insularis Smithers 1962 ¶

Recorded by Watson (1967) as endemic but since recorded from the Antipodes, The Snares, Campbell and Auckland Islands (Smithers 1964, Wise 1977). The genus has several species in New Zealand (Thornton 1985). Winged.

HEMIPTERA: APHIDIDAE

Jacksonia papillata Theobald 1923 ‡

This species occurs in Europe and New Zealand (Eastop 1962, 1970), but is apparently absent from Australia. In Europe it appears to prefer cool, humid climates (M. Carver, pers. comm.).

Rhopalosiphum padi (Linnaeus 1758) ‡

This species has a cosmopolitan distribution, but is rare on Macquarie Island.

Myzus ascalonicus Doncaster 1946 ‡*

Again, this species is rare in Australia but currently very common on Macquarie Island; large numbers were found in green *Acaena* seed heads. It was first identified from Macquarie Island by M. Carver in 1975 (M. Carver, pers. comm.) but was not collected by Watson in 1960, hence may be a recent introduction.

THYSANOPTERA: THRIPIDAE

Physemothrips chrysodermus Stannard 1962 ¶

According to Watson (1967) this species is known only from Macquarie Island but Mound & Walker (1982) record it also from Auckland Island. A darker form was collected on Macquarie in *Azorella* (L. Mound, pers. comm.).

COLEOPTERA: STAPHYLINIDAE

OMALIINAE

Omaliomimus albipenne (Kiesenwetter 1877) ¶

Omalium albipenne Kiesenwetter 1877 = *Omalium variipenne* Lea 1920 *nec* Womersley1937 = *Omaliomimus flavipennis* Cameron 1947

Also known from Auckland and Campbell Islands (Jeannel 1940, Gressitt 1970); a wingless species.

Omaliomimus venator (Broun 1909) ¶

Omalium venator Broun 1909

Also known from Auckland and Campbell Islands (Steel 1964, Watson 1967, Gressitt 1970); a wingless species.

Stenomalium helmsi (Cameron 1945) ¶

Omalium helmsi Cameron 1945

Also known from New Zealand (Watson 1967, Gressitt 1970); winged and often found on carrion (M. Thayer, pers. comm., Newton 1985 as Omaliinae Genus E).

Stenomalium sulcithorax (Broun 1880)¶

Omalium sulcithorax Broun 1880 = *Omalium perplexum* Broun 1894 = *Homalium variipenne sensu* Womersley 1937 nec Lea 1920

Watson (1967), in publishing this synonymy, quoted W.O. Steel's unpublished opinions that the specimens studied by Womersley (1937b) and identified by him as *A. crozentensis* Enderlein were neither that species nor *H. variipenne* Lea but were conspecific with *O. perplexum* Broun. The species is winged and known from carrion. Also found in New Zealand.

Crymus sp. = *Arpediomimus* sp.

Recorded by Steel (1964: 349, M. Thayer, pers. comm.), wings vestigial.

Homalium variipenne Tillyard 1920, *nec* Lea 1920

Probably a larva of uncertain identification (M. Thayer, pers. comm.).

ALEOCHARINAE

Halmaeusa antarctica Kiesenwetter 1877 = *Antarctophytosus macquariensis* Womersley 1937¶

Also known from Auckland Island (Steel 1964, 1970, Watson 1967). The species is wingless and terrestrial.

The Staphylinidae (Omaliinae) are currently being studied by M. Thayer.

BYRRHIDAE

Epichorius sorenseni (Brookes 1951) ¶

Only one adult, one pupa and some larvae known (Watson 1967), identified by Watt (1971). Also known from Campbell Island.

DIPTERA: TIPULIDAE

Erioptera (Trimicra) pilipes macquariensis Alexander 1962 = *Trimicra pilipes* Fabricius 1787 ¶

The nominate species is cosmopolitan. This may be a variety rather than a subspecies as interpreted from Watson (1967) and P. Johns (pers. comm.). The species is known to be variable (P. Johns, pers. comm.), and Macquarie Island specimens exhibit much morphological variation (Alexander 1962) which is within that of Campbell Island and New Zealand populations (P. Johm, pers. comm.). A winged species.

PSYCHODIDAE

Psychoda surcoufi Tonnoir 1922 = *Psychoda spatulata* Satchell 1950 = *Psychoda subimmaculata* Tonn. sensu Womersley 1937 ‡

This species is also known from New Zealand (including Campbell, Auckland and the Antipodes Islands), southern Australia and southern South America (Duckhouse 1985).

Psychoda parthenogenetica Tonnoir 1940 ‡

Psychoda severini parthenogenetica Tonnoir 1940

A species restricted to Europe, Africa, Japan, Australia and New Zealand (Duckhouse 1970, 1971, 1985, Watson 1967) and known also from Crozet, Marion, South Georgia and Kerguelen Islands.

Psychoda alternata Say 1824 §

There is only a single record of this cosmopolitan species from Macquarie Island (Quate 1962) and this species is probably not a permanent resident of the island (Duckhouse 1985).

CHIRONOMIDAE

Telmatogeton macquariensis (Brundin 1962) = *Helirytus macquariensis* Brundin 1962 †

An endemic species according to Watson (1967). Brundin (1962) said it is closely related to the Kerguelen species *Telmatogeton amphibius* (Eaton) with which Sublette & Wirth (1980) agreed and mentioned that it is also close to a species from the Antipodes Islands. Wings strongly reduced.

Smittia sp. ?

Recorded by Brundin (1962) who believed it to be restricted to Macquarie Island; possibly a parthenogenetic species that has bever been described. (Specimens labelled *Pseudosmittia* sp.).

Two further species of chironomid were collected in the summer of 1986–87 in two different genera and are currently being studied by P. Cranston.

SCIARIDAE

Bradysia watsoni Colless 1962 †

An endemic species according to Watson (1967) but there are many undescribed species of sciarids in collections from neighbouring regions (D. Colless, pers. comm.). This species is winged while Heard Island has wingless endemic in this family.

Evenhuis (1989) records another species from Macquarie Island, *Sciara womersleyi* Séguy 1940. This species was erected by Séguy for an unnamed sciarid described by Womersley (1937d) from two females from Kerguelen Island. Womersley also had a single sciarid from Macquarie Island which he believed was the same species. Because *S. womersleyi* was inadequately described, it must remain *species inquirenda* for the present. (D. Colless, pers. comm.)

DOLICHOPODIDAE

Schoenophilus pedestris pedestris Lamb 1909 †

Redescribed by Harrison (1959) and endemic according to Harrison (1976). Another subspecies occurs on Auckland and Campbell Islands. Wings reduced.

HELCOMYZIDAE

Paractora asymmetrica (Enderlein 1930) ? = *Actoceles asymmetrica* Enderlein 1930

Not seen since the original collection which has not been restudied. There is doubt as to the family placing of this species (Harrison 1976).

COELOPIDAE

Coelopella plebeia Malloch 1933 ¶ = *Coelopa macquariensis* Womersley 1937

This species is restricted to Macquarie Island according to Mathis (1989) who is not in agreement with Harrison's (1976) synonymy of this species with *Coelopa Fucomyia curvipes* Hutton 1902 from Auckland and Chatham Islands and New Zealand. McAlpine currently revising the Australian Coelopidae.

Icaridion debile Lamb 1909 ¶ = *Coelopa nigrifrons* Lamb 1909

According to Harrison (1976), this species occurs on Campbell and Auckland Islands, the Antipodes, The Snares and mainland New Zealand as well as Macquarie Island. McQuillan & Marker (1984) omitted to record the synonymy made by Harrison (1976).

CARNIDAE

Australimyza macquariensis (Womersley 1937) † = *Procenace macquariensis* Womersley 1937

Endemic according to Harrison (1976); it is common and belongs to an endemic genus for the New Zealand biogeographic region. Another species in the genus is found in Antipodes, Auckland and Campbell Islands and The Snares.

EPHYDRIDAE

Ephydrella macquariensis (Womersley 1937) † = *Ephydra macquariensis* Womersley 1937

An endemic species for Macquarie Island according to Harrison (1976); Bock (1987) recorded it erroneously from New Zealand subantarctic islands.

Amalopteryx maritima Eaton 1875 #

This species is also known from Heard, Crozet and the Kerguelen Islands according to Womersley (1937d) but is a misidentification for *Apetaenus watsoni* according to

Watson (1967). Only one specimen was recorded by Womersley (1937d).

TETHINIDAE

Apetaenus watsoni Hardy 1962 †

A wingless species and apparently restricted to Macquarie Island according to McQuillan & Marker (1984). Womersley (1937d) recorded this species as *Apetaenus litoralis* Eaton 1875 which is from the Kerguelen Islands, but this is a misidentification according to Harrison (1976). The record is listed in Evenhuis (1989) under *Apetaenus litoralis*.

CHLOROPIDAE

Thyridula sp. ?

Recorded by Sabrosky (1962) from Langdon Point and known from only two specimens which were not studied by Harrison (1976).

LEPIDOPTERA: PYRALIDAE

Eudonia mawsoni (Womersley & Tindale 1937) † = *Scoparia mawsoni* Womersley & Tindale 1937 nov. comb.

Redescribed by Common (1962) and considered endemic, although J. Dugdale (pers. comm.) has compared specimens with congenerics from New Zealand and its subantarctic islands and states that "the genitalia are not readily distinguished from specimens of *Eudonia psammitis* from South Island". The Macquarie Island specimens belong to the New Zealand wide *E. psammitis* (Meyrick) group of populations and this "species has a tendency to have local populations" (J. Dugdale, *in litt.*). The Macquarie Island population is therefore more accurately described as a geographical race rather than a distinct species. Generic name incorrectly used by Common (1962) and Watson (1967) as *Eudoria* (M. Shaffer, *in litt.*).

HYMENOPTERA: DIAPRIIDAE

Antarctopria latigaster Brues 1920 ¶

Recorded by Yoshimoto (1962) and redescribed by Early (1978, 1980). Also known from Stewart, Antipodes, Auckland and Campbell Islands, The Snares and the New Zealand mainland.

Scelionidae gen. et. sp. indet. ?

A single species recorded by Yoshimoto (1962) from Green Gorge but has not been recollected.

ARACHNIDA

ARAENAE: DESIDAE

Myro kerguelenensis Cambridge 1876 ‡ = *Myro hamiltoni* Hogg 1909

Rainbow (1917) redescribed the species *M. hamiltoni* and examined Hogg's types. He commented that *M. hamiltoni* was closely related to *M. kerguelensis* Cambridge. These species were synonymised by Hickman (1939) after examination of Rainbow's material. The species is known from Crozet, Heard, Marion and Kerguelen Islands (Forster 1962, 1970, Lawrence 1971). Lawrence considers it may have been introduced to Marion Island.

LYNPHIIDAE

Parafroneta marrineri (Hogg 1909) ¶ = *Mynoglenes marrineri* Hogg 1909

Also known from Campbell, Auckland, Antipodes and Enderby Islands (Hickman 1939, Watson 1967, Forster & Blest 1979).

Haplinus rufocephalia (Urquart 1888) #
Mynoglenes rufocephalia (Urquart 1888) = *Mynoglenes insolens* Simon 1905

Recorded by Hickman (1939) and also known from Chatham, Campbell and Auckland Islands but according to Watson (1967) may have been misidentified.

HAHNIIDAE

Hahnia sp. #?

Forster (1955) recorded a *Hahnia* species from Auckland Island and quotes that "Hickman (1931)" recorded a species from Macquarie Island. No trace of this record can be found and I conclude that Forster was mistakenly referring to Hickman's (1939) descriptions of *Hahnia crozentensis* from Crozet Island.

Only two species of spiders, *Parafroneta marrineri* and *Haplinus rufocephalia* were collected in 1986/87. Both were common and abundant.

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A NEW SPECIES FROM TASMANIA OF THE FRESHWATER HOPLONEMERTEAN, *POTAMONEMERTES*

by J.L. Hickman and J.Moore

(with two tables and five plates)

HICKMAN, J.L. & MOORE, J., 1990 (31:x): A new species from Tasmania of the freshwater hoplonemertean, *Potamonemertes*. *Pap. Proc. R. Soc. Tasm.* 124(1): 51-59. ISSN 0080-4703. Department of Zoology, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001 (JLH); and Department of Zoology, Downing Street, Cambridge CB2 3EJ, England (JM).

A new species of freshwater hoplonemertean, *Potamonemertes gibsoni*, is described from lakes in Tasmania and its relationship to the type species from New Zealand and to the terrestrial nemerteans of the region is discussed.
Key Words: freshwater, nemerteans, *Potamonemertes*, Tasmania.

INTRODUCTION

All known freshwater hoplonemerteans belong either to the genus *Prostoma* Dugès 1828 (family Tetrastemmidae) or to the monotypic genera more recently described from New Zealand, *Potamonemertes* Moore & Gibson 1973 and *Campbellonemertes* Moore & Gibson 1972. These New Zealand genera are very different from *Prostoma* and have been placed in the same family as the terrestrial nemerteans of New Zealand and Australia, which they closely resemble (Gibson & Moore 1976). Fulton (1983) reported the finding of a nemertean in Great Lake, Arthurs Lake and Lake Sorell, in central Tasmania. The present paper identifies this form as a new species of *Potamonemertes* to be named *P. gibsoni* in tribute to Professor Ray Gibson, Liverpool Polytechnic, England. Since the genus *Potamonemertes* was previously known only from the New Zealand type species, *P. percivali* Moore & Gibson 1973, it is particularly interesting that another species has been found in Tasmania. This paper describes the new species and also considers the distribution of the genus and its relationship to the terrestrial nemerteans of the region.

MATERIALS AND METHODS

Samples were collected between 1975 and 1978 from the floor of Great Lake (11 to 17.5 m) and Arthurs Lake (6.5 to 14 m) on the Central Plateau, using an Ekman grab of 232 cm^2 gape (Fulton 1983). The samples were then sieved (0.7 mm mesh size) and the animals retained by the sieve were preserved in 70% ethanol: some were fixed in Clarke's fixative prior to preservation. The samples were subsequently found to include nemerteans, which were presented to JLH for identification. In total 19 preserved specimens were received and also 11 live nemerteans: these were fixed in hot Susa's fixative, rinsed in iodised 70% ethanol and preserved in 90% ethanol. Twenty-five of the specimens were sectioned at 10 mm and stained in Ehrlich's haematoxylin and eosin. Three specimens were stained in Mallory's triple stain by JM, to facilitate comparison with similarly stained sections of *Potamonemertes percivali*. Fulton (1983) also records the finding of the nemertean in Lake Sorell, Central Plateau, in 1981, and in 1987 further specimens were obtained (using a surber sampler, 500 mm mesh) from the sandy gravel of the Giblin River on the southwestern coast of Tasmania and from Giblin Bay in Lake Pedder — both sites being within the Tasmanian Wilderness World Heritage Area. These were given to JM, sectioned and stained in Mallory's triple stain, and added to the Pantin Collection.

POTAMONEMERTES GIBSONI SP.NOV.

Type Material
(letters in parentheses refer to slide series)

Holotype

Arthurs Lake (West Lake north), 23/7/77, W. Fulton, T.S., 20 slides (S). Tasmanian Museum, Hobart Reg. No. K1135.

Paratypes

Arthurs Lake, 4.iv.77, T.S. 10 slides (H). Pantin collection, British Museum (Nat. Hist.), London (at present in the care of JM at the Zoology Department, Cambridge). Great Lake (Cramps Bay), 4.xii.75, T.S. 19 slides (E); Arthurs Lake (East Lake south), 10.x.77, L.S. 10 slides (0); Arthurs Lake (East Lake north), 24.i.77, H.S., 3 slides (W); Great Lake (Brandum Bay), 2.vi.75, H.S. 5 slides (BB); Arthurs Lake (Tea-tree Bay), 28.xi.77, H.S. 9 slides (EE).

Tasmanian Museum, Hobart Reg. Nos. K1136 (T.S. 19 slides); K1137 (L.S. 10 slides); K1138 (H.S. 3 slides); K1139 (H.S. 5 slides); K1140 (H.S. 9 slides)

Distribution

The species has been recorded only from Tasmania. It has been found on the Central Plateau at Arthurs Lake, Great Lake and Lake Sorell; and in the Tasmanian Wilderness World Heritage Area at Giblin River on the southwestern coast and Giblin Bay in Lake Pedder.

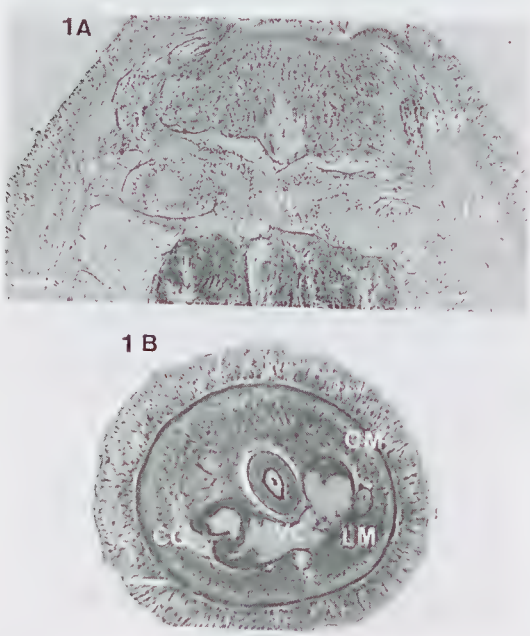

PLATE 1

Potamonemertes gibsoni *sp.nov. (A) LS anterior region; (B) TS brain region. Showing the relative thickness of circular muscle* (CM) *and longitudinal muscle* (LM)*, the ventral cerebral commisure* (VC) *and the posterior extent of the cephalic gland* (CG)*. Scale bar=500* µm *for both.*

Appearance in Life and Behaviour

The specimens were pale red to white in colour and small, attaining a maximum length of 20 mm. Spontaneous fragmentation was pronounced. This phenomenon has been observed in certain terrestrial nemerteans when in poor condition, and recorded from the Australian terrestrial nemertean *Argonemertes stocki* which shows controlled fragmentation of the posterior end into millimetre cubes (Moore 1975), but has not been recorded from any freshwater nemertean other than *Potamonemertes percivali.* Percival in 1943 recorded that "The animals were difficult to take whole, as they fragmented quickly and easily" (pers. comm. to Dr C.F.A. Pantin). This also was the experience of JM on revisiting Percival's type locality in January 1988 to observe *P. percivali.*

Anatomy

The general morphology of the present specimens is similar to that described by Moore & Gibson (1973) for *Potamonemertes percivali.* A full anatomical description is thus unnecessary. In the following brief account emphasis is given to characters significant in the taxonomy of related genera and to points of comparison with *P. percivali.*

Measurements made on the histological preparations are recorded where relative values may be interesting. However, living specimens were up to 20 mm in length while preserved mature specimens ranged from 2.5 to 8 mm. Such shrinkage is usual in nemerteans which have not been narcotised before preservation, and may occur unevenly.

Body Wall

The body is covered by a thick (35–80 mm) ciliated epidermis including gland cells. The underlying dermis, composed of connective tissue, is relatively thick (5–13 mm). The musculature is (as in *P. percivali*) particularly well developed for a small nemertean, most especially in the anterior part of the body. Whereas in *P. percivali* the two muscle layers are approximately equal in thickness, in the present specimens the longitudinal muscle layer of the anterior region (12.5–137 mm) is considerably thicker than the circular muscle (5–25 mm) (pl. 1A,B).

Parenchyma

Parenchyma is fairly extensive in most parts of the body posterior to the pyloric region.

Rhynchocoel

This is "full body length", i.e. extends to within 100 to 500 mm of the posterior tip of the body. Its muscular wall can be described as a single layer composed of circular, longitudinal and oblique fibres: it is constructed as a wickerwork of circular and longitudinal muscle fibres as is characteristic also of the Australian and New Zealand land nemerteans and other related forms. According to Gibson (1988) this character state defines a major subdivision of the hoplonemerteans, the Paramonostilifera (pls 2A, 5A).

Proboscis

This is very large, being approximately 1/2 to 3/4 the length and 1/5 to 1/3 the diameter of the worm. Everted, it measures 3/4 to 1 1/3 the length and 1/3 to 2/3 the diameter of the worm. The anterior proboscis consists of the usual layers, without muscle crosses and without enclosure of circular muscles in the dermis. There are 12–18 proboscis nerves. The stylet region includes 2–4 accessory stylet sacs each containing 3–7 stylets which measure 60–87mm in length and 15–20 mm in diameter at their base. Unlike *P. percivali* each accessory sac has a duct which opens near the base of the main stylet (pl. 2B). The main stylet measures 43–70 mm in length and 13–20 μm in diameter at its base. The basis is urn shaped 65×42.5–126×78 mm.

Gut

The gut is typical: the oesophagus is a short unciliated tube leading from the rhynchodeum into the large glandular stomach (approximately 1/10 the length of the worm) which extends posteriorly as a wide dorsoventrally flattened pyloric tube (1/6 to 1/17 the length of the worm) leading to the intestine. From the point where the pylorus joins the intestine a ventral caecum extends anteriorly, ventral to the pylorus, and bifurcates into blind diverticula 100–350 mm long, which extend forwards to the brain.

Eyes

Eyes are absent. This character state is shared by *P. percivali*, *Campbellonemertes*, one species of *Prostoma* and all known freshwater heteronemerteans. Most marine and all known terrestrial nemerteans possess eyes.

Cerebral Organs

As in *P. percivali* these open laterally from short longitudinal epidermal furrows. However, they are much larger and have a different shape. The cerebral canal passes posteroventrally from the furrow for 100–125 mm to enter the ganglionic mass which is ovoid (60×62–100×125 mm) and situated anterolateral to the ventral cerebral ganglion. Within the mass the canal passes round to the ventral and inner posterior region where it ends blindly among the cerebral gland cells. Although the canal does not fork, in some sections a very small dorsal diverticulum appears to be present where the canal enters the ganglionic mass. The cerebral gland cells extend backwards for 110–200 mm along the ventro-lateral aspect of the dorsal cerebral ganglion to nearly level

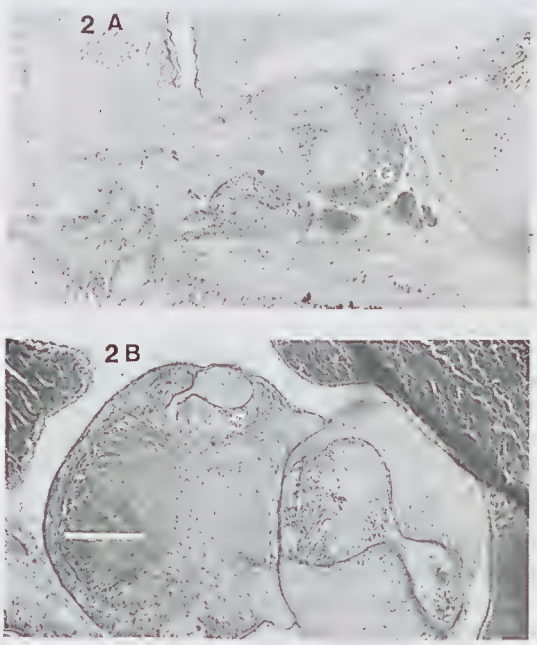

PLATE 2

Potamonemertes gibsoni *sp. nov. (A) LS to show the cerebral organ: the cerebral canal opening* (O) *and the ganglionic region* (G) *beside the ventral cerebral ganglion* (VG) *are evident; the wickerwork structure of the rhynchocoel wall musculature* (RM) *is also shown. (B) Stylet region of proboscis to show an accessory stylet sac* (ASS) *with duct. Scale bar = 100 μm for both.*

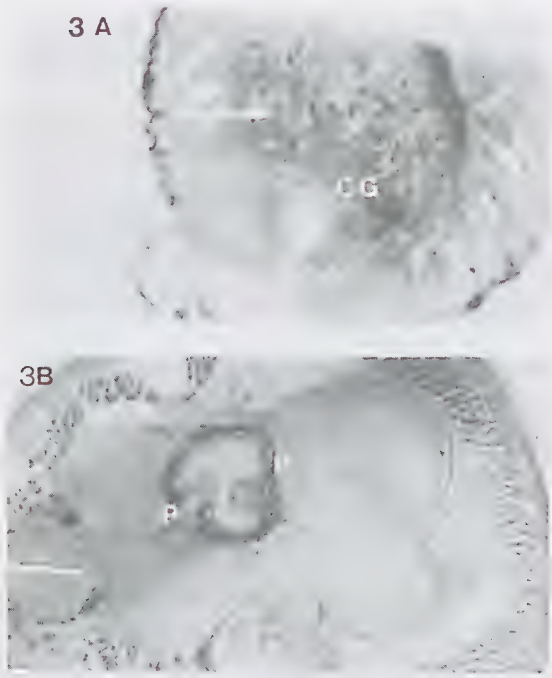

PLATE 3

Potamonemertes gibsoni *sp. nov. (A) LS anterior end to show the discharge of the cephalic glands* (CG) *into the frontal organ* (FO)*; scale bar = 50 μm. (B) TS brain region to show the two vascular plugs* (P) *and the posterior extent of the cephalic gland* (CG)*; scale bar = 200 μm.*

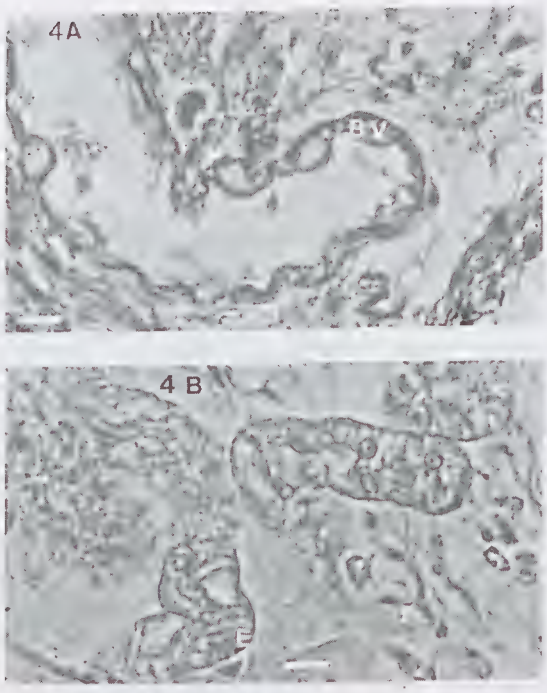

PLATE 4

Potamonemertes gibsoni *sp. nov. (A) Lateral blood vessel* (BV) *to show valves in the wall. (B)Excretory ducts* (E) *and flame cells* (F)*. Scale bar = 30 μm for both.*

with the posterior margin. The cerebral gland has a maximum diameter (40–75 mm) where it adjoins the ganglionic mass (pl. 2A).

Frontal Organ

There is a small but distinct frontal organ, 50–80 mm in diameter, through which the cephalic glands discharge (pl. 3A). The organ opens into a cavity approximately 15 mm in diameter and 30 mm in depth. In *P. percivali* the frontal organ and cephalic glands are described as having separate openings.

Cephalic Gland

This is considerably larger than in *P. percivali* where it is restricted to a small anterior dorsal cap. In the new species, the gland (consisting solely of basophilic lobules) extends back, 212–464 mm, as far as the posterior surface of the dorsal cerebral ganglion (pls 1B, 3B).

Nervous System

The nervous system is typical of hoplonemerteans but lacks the posterior protuberances on the ventral cerebral commissure which constitute a unique feature of *P. percivali*: this must therefore be seen as a specific rather than a generic specialisation. The present specimens resemble *P. percivali* in having no neurochord cells, no accessory lateral nerve and no dorsal contribution to the lateral nerve from the dorsal cerebral ganglion.

Vascular System

As in *P. percivali* and all other known freshwater nemerteans, the only cross-connections present between the dorsal and lateral blood vessels are the cephalic loop, which passes through the cephalic gland, and the supra-anal commissure. Accordingly the two vascular plugs are borne on the lateral vessels, anterior to the origin (from one lateral

vessel) of the mid-dorsal vessel. The plugs (about 70 mm in diameter) project into the rhynchocoel in the cerebral region (pl. 3B). The lateral vessels, as in *P. percivali*, are lacunar but smaller, and valves (rare in *P. percivali*) are evident in the blood vessels of the present specimens (pl. 4A).

Excretory System

The excretory system does not differ from that of *P. percivali*: it is very well developed and extends throughout the animal. Simple paired mononucleate flame cells lead into excretory ducts which open by a very large number of small pores. The excretory ducts are thick walled with the specialised structure unique to Australian and New Zealand terrestrial nemerteans and *Potamonemertes* (pls 4B, 5A).

Gonads

The animals are simultaneously hermaphroditic and probably also variably protandrous. As in *P. percivali*, the testes generally extend further forward than the ovaries, however, there is no sharp separation of the testicular from the ovarian field. Testes may occasionally occur as far forward as the brain but more commonly extend posteriorly from the region of the pyloric tube, being dorsal, lateral and ventral in position (pl. 5B). The maximum dimension of mature testes varies from 125–192 mm and that of mature ovaries from 230–272 mm. Ripe ova measure 224–272 mm and have nuclei 56–64 mm in diameter.

GENERIC DIAGNOSIS AND SPECIFIC DIFFERENCES

Now that a second species of *Potamonemertes* has been described, a generic diagnosis can be given and the specific differences between the type species from New Zealand, *P. percivali*, and the present Tasmanian species, *P. gibsoni*, can be tabulated.

Potamonemertes Moore & Gibson 1973

Diagnosis

Freshwater Paramonostilifera with body wall musculature particularly well developed in anterior portion of body; epidermis typical, dermis thick, parenchyma extensive in most of body; rhynchocoel full body length with wall composed of wickerwork of interwoven circular, oblique and longitudinal

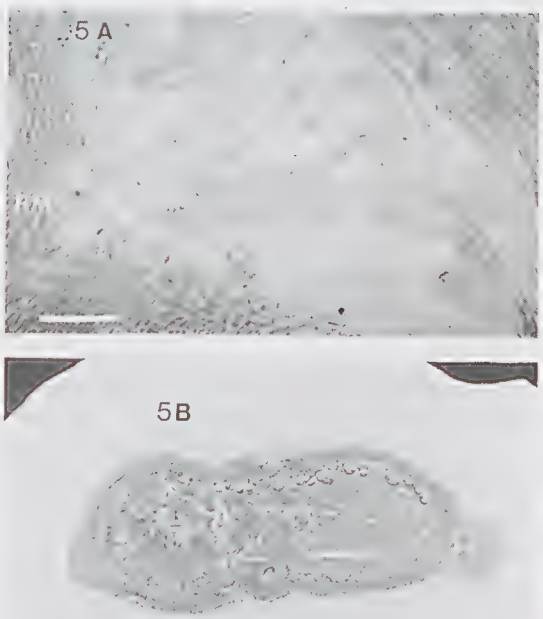

PLATE 5

Potamonemertes gibsoni *sp. nov. (A) Excretory ducts* (E)*, flame cells* (F) *and rhynchocoel musculature* (RM)*; scale bar = 100 µm. (B) LS to show the position of the gonads: ovaries*(O)*, testes* (T)*; scale bar = 1000 µm.*

muscle fibres; proboscis massive and at least as long as the body; alimentary canal with mid-ventral caecum bearing anterior diverticula; eyes absent; cerebral organs anterior, with canal unforked and no anterior sac, opening into a pair of lateral longitudinal cephalic furrows; frontal organ present, cephalic gland opening to the exterior through a single pore which is either the frontal organ or a small median pore dorsal to it; nervous system with no neurochord cells, no accessory lateral nerve and no contribution from the dorsal cerebral ganglion to the lateral nerve; blood vascular system with lacunar lateral vessels and mid-dorsal vessel arising from one of them post-cerebrally, these vessels having no commissural connection other than the cephalic vascular loop and the supra-anal commissure; two vascular plugs, borne on the two lateral vessels, projecting into the rhynchocoel in the cerebral region; excretory system extending throughout body consisting of simple paired mononucleate flame cells and excretory ducts opening by numerous pores, these ducts being thick walled specialised structures; hermaphrodite, simultaneous, and

probably variably protandrous, gonads either sharply regionalised or overlapping with testes at least extending further forward than ovaries; readily fragments.

FAMILIAL PLACING OF *POTAMONEMERTES*

Potamonemertes and *Campbellonemertes* were originally placed in the family Prosorhochmidae, with the undivided genus *Geonemertes* (Moore & Gibson 1972, 1973). Further information about the convergent origin of terrestrial nemerteans led to the splitting of the genus *Geonemertes* (Moore & Gibson 1981) and the recognition of two distinct groups of land nemerteans. Redescription of the genus *Prosorhochmus* (Gibson & Moore 1985) established that only the first group of land nemerteans (the redefined genus *Geonemertes*, and *Pantinonemertes*) should remain in the Prosorhochmidae. *Potamonemertes* and *Campbellonemertes* belong with the Australian terrestrial genus *Argonemertes*, the New Zealand terrestrial genus *Antiponemertes*, and *Acteonemertes* in the newly erected family Plectonemertidae (Moore & Gibson 1988) which includes forms with wickerwork rhynchocoel musculature, two vascular plugs and other uniting characters (see table 1).

DISCUSSION

We now have further knowledge of the distribution of *Potamonemertes* and a better basis for distinguishing the generic from the specific characters. Do we, however, have further clues to its evolutionary history? That species of the same freshwater genus should occur both in New Zealand and in Tasmania is not unusual, being known to occur, for example, in the following genera, Coleoptera: *Hydraena*, *Meropathus*; Crustacea: *Boeckella*; Mollusca: *Gyraulus*, *Physastra*, *Sphaerium*; Platyhelminthes: *Temnocephala*, *Cura*. While *Potamonemertes* is known only from New Zealand and Tasmania, and *Campbellonemertes* only from one species on Campbell Island, the other freshwater hoplonemertean genus, *Prostoma*, is worldwide in distribution. In many countries details of its occurrence are unknown: in Tasmania it appears only to occur in areas which have been settled at one time or another by Europeans, suggesting that it may have been introduced. Both *Potamonemertes* and *Campbellonemertes* resemble the terrestrial nemertines of New Zealand (the genus *Antiponemertes*, and the upper littoral/terrestrial genus *Acteonemertes*) and Australia (the genus *Argonemertes*) in morphology as well as geographical distribution (see table 1). *Potamonemertes* and *Campbellonemertes* are unlike terrestrial nemerteans and resemble each other in the rather mysterious "freshwater features" concerning absence of eyes, absence of cross connections between the longitudinal blood vessels and being hermaphroditic (but *Argonemertes dendyi* is one terrestrial nemertean which also is hermaphroditic). Absence of eyes in freshwater forms may be indicative of the animals living within the organic debris and silt in the bed of the stream, pond or lake. Similarly among the terrestrial turbellarians, eyes are extremely well developed along the lateral margin of the rather flat body of those species which feed on the surface inhabiting fauna. During the day they can be found in crevices in logs or under logs, stones and litter. They probably use their eyes to detect (among other things) the light intensity gradient within which they can safely move and feed. A few species are blind and during the day are found in cavities under stones and logs. These may well feed on fauna below the surface, in cavities such as burrows or tunnels in the ground or in logs. Apart from the "freshwater features" *Potamonemertes* and *Campbellonemertes* do not seem to be particularly closely related within the family: *Campbellonemertes* is quite different in size and shape and has a great many specialisations. It is *Potamonemertes* which more closely resembles terrestrial nemerteans, in particular in having a very large proboscis and the specialisation of the excretory ducts which is otherwise unique to *Argonemertes* and *Antiponemertes*.

Moore & Gibson (1973) built on this resemblance to postulate an evolutionary sequence: they suggested that *Potamonemertes* may have colonised freshwater by way of the land. The points of resemblance are functionally appropriate for terrestrial nemerteans, for example a greatly enlarged proboscis which is used for quick escape movements is almost universal among terrestrial nemerteans of both families (Prosorhochmidae and Plectonemertidae). Further, in contrast to *Prostoma*, *Potamonemertes* and *Campbellonemertes* belong to a family with no known estuarine species. However, this hypothesis is not supported by cladistic analysis (Sundberg 1989) and must remain in doubt. Some marine features which *Potamonemertes* has retained which conceivably would have been modified had its progenitors been terrestrial are: (a) the lateral longitudinal furrows into which the cerebral organs open; (b) the presence of a frontal organ; (c) the

TABLE 1
Comparison of *Potamonemertes* with Australian Land and Freshwater Genera and with *Prostoma*

	Acteo-nemertes	*Antipo-nemertes*	*Argo-nemertes*	*Potamo-nemertes*	*Campbello-nemertes*	*Prostoma*
Rhynchocoel musculature: wickerwork (+), separate layers (0)	+	+	+	+	+	0
Rhynchocoel full body length (+), much shorter (0)	+	+	+	+	+	0
Number of vascular plugs	2	2	2	2	2	1
Body musculature well developed with thick dermis (+), not so (0)	+	+	+0	+	+	0
Parenchyma extensive (+), sparse (0)	+	+	+	+	+	0
Proboscis large, active in locomotion (+), not so (0)	+	+	+	+?	0	0
Gut with pyloric tube and ventral caecum (+), without (0)	+	+	+	+	+	0
Anterior caecal diverticula long (++), short,variable (+)	++	+	++	+	+	++
Frontal organ present (+), absent (0)	0	0	0	+	0	+
Cephalic gland opens into frontal organ or nearby duct (+) or into improvised openings (0)	0	0	0	+	0	+
Cephalic gland very extensive (++) fairly extensive(+), restricted (0)	++	++	++	+0	++	+0
Cerebral organ large with forked canal (++) unique specialization(+), smaller and simple (0)	0	++	++	0	+	0
Multiplication of excretory ducts and pores very great (++), slight (+)	++	++	++	++	++	+
Excretory ducts with specialised region (+), uniform (0)	0	+	+	+	0	0
Habitat:Upper littoral (UL), Terrestrial (T), Freshwater(FW)	UL	T	T	FW	FW	FW
Number of eyes	4–6	2–4	20–180	0	0	0–6
Cerebral organ opens into lateral longitudinal furrows (0), single ventral transverse furrow (+)	+	+	+	0	0	0
Blood vessels with capillary net work extensive (+), without cross links between cephalic & anal region (0)	+	+	+	0	0	0
Gonads: hermaph.(+), single sex (0)	0	0	0+	+	+	+

cephalic gland opening confluent with the frontal organ and (d) the rather limited development of the cephalic gland. Other features, however, are suggestive of a prior terrestrial existence, for example, (a) the multiplication of excretory ducts; (b) the regional specialisation of the excretory ducts; (c) the small size of the frontal organ and (d) the relatively large proboscis. Whatever the evolutionary sequence, there is no doubt that *Potamonemertes* and *Campbellonemertes* are closely related to the land nemerteans of Australia and New Zealand and are far removed from *Prostoma* which originated elsewhere.

Comparison of the two species of *Potamonemertes* (table 2) shows that in every point of difference it is the Tasmanian species, *P. gibsoni*, which is less specialised. The ventral cerebral commissure is normal in form, as are the body wall muscle, oesophagus, blood vessels and stylet region. The unusual regional division of the gonads is less marked in *P. gibsoni*. Possession of a frontal organ (by both species) is a common feature of marine nemerteans but is in strong contrast to the less restricted outlet for the mucus secretion found in terrestrial forms in the Plectonemertidae (presumably reflecting the greater demand for copious mucus secretion in the terrestrial forms). The amount of cephalic gland present in *P. gibsoni* is nearer to that of the terrestrial genera. Of the two species, then, it is the Tasmanian one which more closely resembles both the terrestrial nemertines and their marine relatives. Whether the ancestors of *Potamonemertes* colonised freshwater directly (up rivers) or by an overland route (thus requiring them to first become completely terrestrial) or via lagoons and swamps (the conditions of which fluctuated in such a way as to favour the emergence of some terrestrial preadaptation but also an adaptation to freshwater), it is tempting to suppose that this might have happened in Australia rather than New Zealand. It is hard to decide whether *Potamonemertes* is closer to *Argonemertes* or *Antiponemertes*: these two genera differ primarily in the number of eyes, and *Potamonemertes* has none. Differences between *Argonemertes* and *Antiponemertes* concerning the size of the posterior gland of the cerebral organ, the mobility of the stomach and the relative length of the anterior caecal

TABLE 2
Differences Between the Two Known Species of *Potamonemertes*

	P. percivali	*P. gibsoni*
Sites of occurrence	New Zealand: Coe's Ford, Selwyn River, Canterbury	Tasmania: Great Lake, Arthurs Lake, Lake Sorell, Lake Pedder, Giblin River
Ventral cerebral commissure	With posterior protuberances	Normal, i.e without posterior protuberances
Cephalic gland	Small dorsal/anterior cap only. Opens by separate pore dorsal to frontal organ	Extends from anterior to brain region. Opens through frontal organ
Cerebral organ	Ganglionic mass elongate and small, less than one third of the size of the ventral cerebral ganglion; gland short	Ganglionic mass compact nearly spherical and nearly as large as ventral cerebral ganglion; gland elongated
Oesophagus	Ciliated	Unciliated
Body wall muscle	Longitudinal and circular layers equally well developed	Longitudinal muscle layer much thicker than circular in anterior part of body
Blood vessels	Very large lacunae	Moderate sized lacunae
Stylet region	Valves rare No canals between accessory sacs and main stylet	Valves common Canals present
Gonad distribution	Sharply regionalised	Testes and ovaries extensively overlap

diverticula are not sufficiently marked for any hypothesis. The two terrestrial genera are distinctly different in behaviour (Moore 1989) but this is no help. All that can be said is that the New Zealand species of *Potamonemertes* has more secondary specialisations than the Tasmanian one.

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TRIASSIC SANDSTONE PETROLOGY OF TASMANIA: EVIDENCE FOR A TASMANIA–TRANSANTARCTIC BASIN

by J.W. Collinson, J.T. Eggert and N.R. Kemp

(with eight text-figures and five tables)

COLLINSON, J.W., EGGERT, J.T. & KEMP, N.R., 1990 (31:x): Triassic sandstone petrology of Tasmania: evidence for a Tasmania–Transantarctic Basin. *Pap. Proc. R. Soc. Tasm.* 124(1): 61–75. ISSN 0080–4703. Byrd Polar Research Centre & Department of Geology and Mineralogy, Ohio State University, Columbus, Ohio 43210, USA (JWC); Arco Alaska, Inc., P.O. Box 100360, Anchorage, Alaska 99510, USA (JTE); and Tasmanian Museum, GPO Box 1164M, Hobart, Tasmania, Australia 7001 (NRK).

Similar fluvial sequences of Triassic age occur in Tasmania and the Transantarctic Mountains of Victoria Land. The Tasmanian reference section at Poatina consists of Lower Triassic quartzose fluvial sandstones overlain by Middle and Upper Triassic volcaniclastic fluvial sandstones and shale containing coal. Similar, but less well-exposed sequences, occur in many places in Tasmania and in southern Victoria Land. The hypothetical Tasmania–Transantarctic basin was similar in scale, configuration, and history to the Sydney foreland basin. Palaeocurrent data suggest that streams flowed along the axis of the basin from Antarctica to Tasmania. Lower Triassic sandstones were deposited by braided streams, but Middle and Upper Triassic stream deposits change from braided to meandering downstream toward Tasmania. Quartzose sandstones in the Lower Triassic were derived from northwestern Tasmania and the East Antarctic craton. The source of volcaniclastic sandstones in the Middle and Upper Triassic was a calcalkaline volcanic arc along the palaeo-Pacific margin.
Key Words: Triassic, Tasmania, sandstone petrology, foreland basin, Antarctica, Gondwana.

INTRODUCTION

Prominent features of the landscape of central and eastern Tasmania are the dolerite-capped cliffs of Triassic sandstone along the margins of plateaus. Similar plateaus demonstrating the same stratigraphic relationships are characteristic of parts of the Transantarctic Mountains along the Ross Sea. The similarity between these landscapes on opposite sides of the Southern Ocean is striking. Are the similarities superficial or are the rocks that characterise these landscapes closely related to each other in a reconstructed Gondwanan supercontinent? The Jurassic dolerites have a similar chemical signature that is unique to Tasmania and the Transantarctic Mountains. The Triassic sandstones, representing ancient river systems, are by their nature more complex. Our objectives are (1) to document the sandstone petrology of the stratigraphic section at Poatina, which serves as a reference section for the Triassic of Tasmania, (2) to identify major patterns in Triassic fluvial deposition, as indicated by environments of deposition, palaeocurrent patterns, and composition of sandstones as related to changing source areas, and (3) to relate the Triassic of the Tasmania basin to its palaeogeographic setting near the palaeo-Pacific margin of the Gondwanan supercontinent.

Reviews of the Triassic System in Tasmania include Banks (1973, 1978), Hale (1962), and Forsyth (1984, 1989). Maps and explanatory reports published by the Department of Mines and unpublished theses by students at the University of Tasmania have also contributed much to the knowledge of Triassic rocks in various parts of the state.

Fieldwork for the project was carried out from February to May 1980, with field checks in August 1982 and April 1988. A detailed petrologic analysis of Triassic sandstones was reported by Eggert (1983) in a Master's thesis at the Ohio State University. Additional information on measured sections and crossbedding data is detailed in this thesis, which is on file in the library at the University of Tasmania. Sample numbers refer to a collection of thin sections and slabs from 228 surface samples and 37 core samples housed in the Department of Geology, University of Tasmania.

STRATIGRAPHY

A variety of stratigraphic names has been applied to the Triassic rocks in Tasmania. Deposited in a single large fluvial system, most lateral differences in rock type are local facies variations. These facies changes and the difficulty of correlating stratigraphic units across fault blocks have resulted in a proliferation of

local stratigraphic names. Formal stratigraphic names for Triassic units have not been applied on quadrangle maps of the Department of Mines since 1963. Instead, letters descriptive of rock types or facies, such as TRp (quartz sandstone), TRm (muddy fluvial plain facies), TRs (quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone) are assigned (Forsyth 1984). While portraying a useful description of rock units on a quadrangle map, these informal names are inadequate for regional discussions such as this.

From a descriptive standpoint, all Triassic rocks in Tasmania can be grouped into two lithostratigraphic units. The lower unit is characterised by quartzose sandstone and the upper unit by volcanic lithic sandstone and shale with coal toward the top of the section. Following Banks & Clarke (1973), we will use the nomenclature proposed by McKellar (1957) for the most complete and best exposed sequence of Triassic rocks in Tasmania, which is near Poatina along the northern margin of the Western Tiers (fig. 1). Because McKellar's descriptions and thicknesses are largely based on several cores, none of which fully penetrate the Triassic section, much confusion on the position of contacts at the surface exists. A proposal under consideration by the Department of Mines (S.M. Forsyth, personal communication) to obtain a complete core from a single borehole would be a great contribution to the knowledge of Tasmanian geology. The extensive

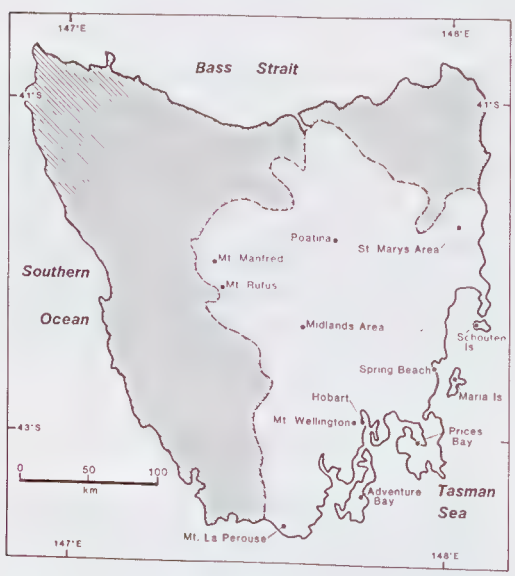

FIG. 1 — Map of Tasmania showing localities referred to in the text. Diagonal pattern outside of the area of known Triassic exposures.

mapping and palynologic studies of Triassic rocks underway by Forsyth (e.g. 1984, 1989), which are summarised in Forsyth (1989), will eventually lead to detailed correlations and perhaps a new stratigraphic nomenclature acceptable to everybody. A better knowledge of the microfloral sequence in Tasmania is essential to the interpretation of microfloras in Antarctica. Sections in the Transantarctic Mountains may be better exposed, but the intensity of Jurassic intrusions has seriously damaged the microfloral record (Collinson 1990b).

The Parmeener Supergroup includes the Upper Carboniferous to Triassic sequence (Banks 1973). The Upper Parmeener Supergroup comprises the uppermost Permian and Triassic fluvial deposits. The lower part, including the Upper Permian and Lower Triassic, is composed predominantly of quartzose sandstone; the upper part, including the Middle and Upper Triassic, is dominated by shale and volcaniclastic sandstone. Coal occurs in both the Upper Permian and Upper Triassic. Late Permian floras are separated from Early Triassic microfloras by a widespread disconformity, with coal-bearing, somewhat feldspathic sandstone below and more quartzose sandstone with rare carbonaceous material above. Biostratigraphic control is not sufficient to determine whether this lithological break represents a hiatus across the Permian–Triassic boundary (Banks 1962, Banks & Naqvi 1967). The youngest unit with Permian fossils is the "Upper Freshwater Sequence", which is generally referred to as the Cygnet Coal Measures. Banks & Clarke (1987) interpreted these rocks to represent a sandy coastal plain sequence. In north-eastern Tasmania, particularly in the area around St Marys, Middle Triassic fluvial sediments disconformably overlie Upper Permian marine beds, indicating a hiatus (Turner & Calver 1987). Regional truncation of Permian beds suggests slight tilting and erosion just before Middle Triassic deposition.

McKellar (1957) assigned the following formational names to the Triassic succession exposed along the Western Tiers (in ascending order): Ross Sandstone, Cluan Formation, Tiers Formation, and Brady Formation. Although these formations were originally based on cores, an excellent reference section, graphically depicted in figure 2, is exposed along the Poatina highway ascending the Western Tiers (Banks & Clarke 1973). This highway did not exist at the time McKellar completed his work. The palynostratigraphy of this sequence is somewhat known from the work of Playford (1965) and can be correlated with other sequences in Tasmania (Forsyth 1984, 1989).

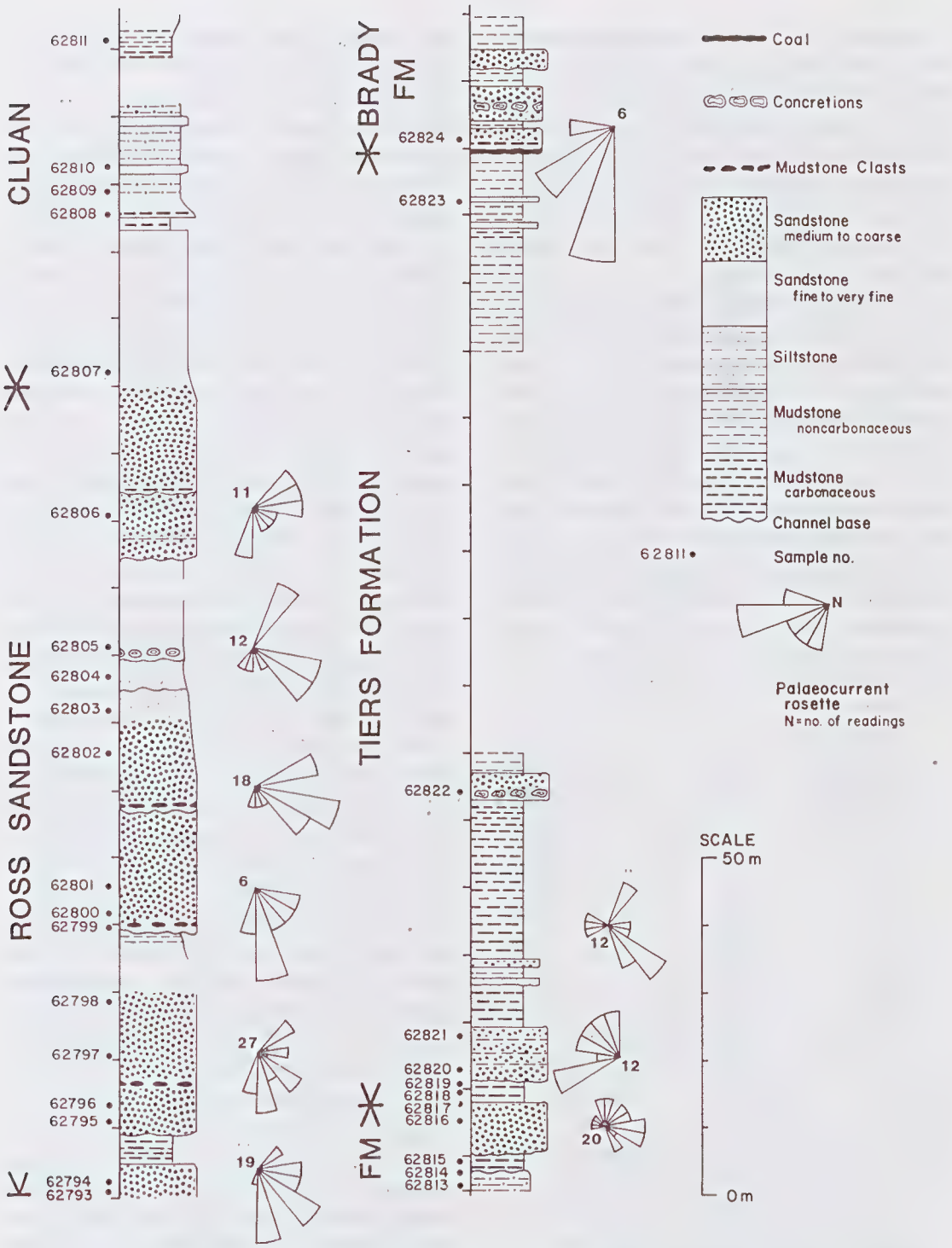

FIG. 2 — Triassic reference section along Western Tiers highway near Poatina. Sample numbers refer to the collections of the Department of Geology, University of Tasmania. Palaeocurrent rosettes are comparative; the frequencies counts for each class interval (20°) are converted to percentages of the total data set and these values are used as the radii lengths of the sectors. Plots were made by a computer program called "Sphere", which is being developed by Phil Ingram, School of Earth Sciences, Macquarie University.

McKellar (1957) described the Ross Sandstone as an "... impure, medium-grained quartz sandstone" marked by a line of cliffs along the face of the Tiers near Poatina. He noted that cores, which penetrated into the upper part of the formation, were entirely of sandstone and varied only in grain size. Our measured outcrop thickness of 170 m is less than the 650 ft (200 m) thickness reported by McKellar, which was based on 270 ft (83 m) of drill core plus an additional 380 ft (117 m) from "surface mapping".

The Ross Sandstone at Poatina disconformably overlies carbonaceous shale of the Jackey Shale, a correlate of the Cygnet Coal Measures. As noted by Forsyth (1984) in the Midlands area, the basal disconformity is no more pronounced than channel bases throughout the sequence. The formation is dominated by 5–20 m thick sandstone cycles separated by major channel scours. Mudstone clasts are commonly associated with these scours. Sandstones are coarse- to medium-grained, except near the tops of cycles where they may be fine-grained. Thin lenticular mudstones occur locally along bedding surfaces. Large-scale trough cross-bedding in sets averaging about 0.5 m thick predominates, but larger sets of tabular cross-bedding are also common. Cross-beds are commonly overturned. Finer-grained beds exhibit planar and ripple lamination.

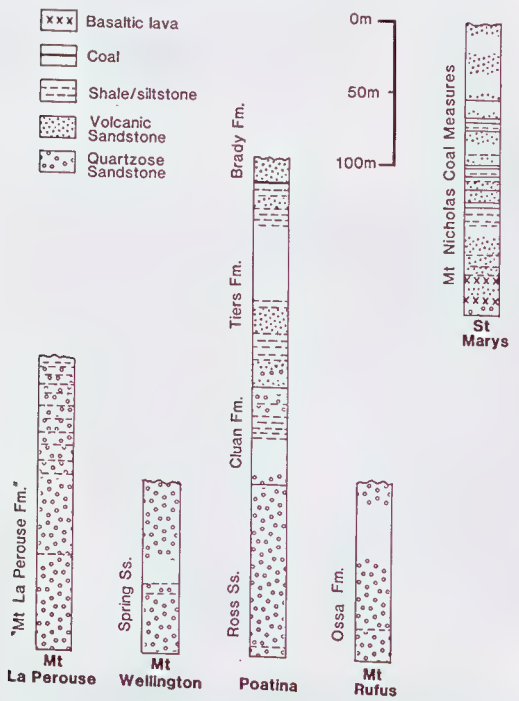

FIG. 3 — Selected stratigraphic columns in NE-trending traverse across Tasmania basin.

The Ross Sandstone and its equivalents are early Early Triassic (Scythian) in age (Forsyth 1989). This resistant sandstone unit ranges between 100 m and 200 m thick, forming prominent cliffs throughout the Tasmania basin. The lower 125 m of the Triassic System (Davidson 1969) on Mt La Perouse and the Mountain Lodge Member of the Springs Sandstone on Mt Wellington (Banks 1978) fit the above description of the Ross Sandstone (see stratigraphic sections in figure 3). The Ossa Formation, which overlies the Upper Permian coal measures in the northwestern part of the Tasmania basin (e.g. Mt Rufus and Mt Manfred sections), is also similar, but generally coarser grained.

The name "Cluan Formation" was assigned to fine- to medium-grained quartzose sandstone interbedded with dark-grey shale and siltstone overlying the Ross Sandstone. McKellar reported a 460 ft (142 m) thickness based on cores, which is greater than the 113 m thickness that we measured along the Poatina highway. The lower 65 m is dominated by fine-grained quartzose sandstone. The upper 48 m contains some medium- to coarse-grained quartzose sandstone, but is dominated by fine- to medium-grained volcaniclastic sandstone. Carbonaceous mudstone and siltstone become more abundant upward in the section. Sandstone units are trough cross-bedded. The Cluan is assigned a late Early to early Middle Triassic (Scythian–Anisian) age based on the correlation suggested by Forsyth (1989). Fine-grained sandstones that form the top of Mt La Perouse also may be equivalent (fig. 3).

The Tiers Formation was described as a grey-green, khaki-weathering shale and "felspathic" sandstone, differing from the overlying Brady Formation in a lack of coal seams (McKellar 1957). Sandstone units are generally thinner than in the underlying formations and are interbedded with greenish-grey and grey carbonaceous siltstone and shale. Root casts and fossil plant material are common and coalified logs occur locally. The slope-forming, crumbly character of the formation is due to the predominance of mudstone and the easily weathered volcanic lithic component of the sandstone. Thin beds of quartzose sandstone occur near the base of the formation in the cores and in the transition between the Cluan and Tiers Formations along the Poatina highway. McKellar (1957) picked one of these quartzose units in the cores as the base of the Tiers, giving a total thickness of 280 ft (86 m) for the formation. This thickness is close to the 97 m thickness in the section along the Poatina highway,

which is poorly exposed. The Tiers Formation is Middle Triassic (Anisian-Ladinian) in age (Forsyth 1989). Forsyth (1984) described Tiers-equivalent units on the Oatlands Sheet.

McKellar (1957) described the Brady Formation as consisting of fine- to medium-grained "felspathic" sandstone, dark-grey shale, and coal seams ranging in thickness from 0.5 ft (15 cm) to 5 ft (1.5 m). The dominant rock types are greenish-grey and grey carbonaceous siltstone and shale. Sandstones are typically greenish-grey or greenish-brown, reflecting alteration of the volcanic component. The thicker sandstone bodies are channel-based and fine upward. Basal scours contain intraformational clay-pellet conglomerate and quartz, quartzite, and granitic clasts. Fossil plant material is common and silicified wood occurs locally. Based on the cores, McKellar (1957) noted a 540 ft (166 m) thickness for the formation. Only the lower part of the formation is well exposed along the Poatina highway (fig. 2). The base of the formation was selected at the base of the lowest coal seam. Sandstones in the Poatina cores are generally volcaniclastic. Sandstone samples from our measured section of the Mt Nicholas Coal Measures in the St Marys area (fig. 3), from the New Town Coal Measures in Hobart, and from coal-bearing beds on Schouten Island are indistinguishable from those of the equivalent Brady Formation. Forsyth (1984) has correlated these units with volcanic lithic arenite, lutite and coal measures in the Oatlands area. In the St Marys area two basaltic lava flows in the lower part of the Upper Parmeener Supergroup give radiometric ages of 233 ± 5 Ma (Calver & Castleden 1981). Palynological analysis suggests an Anisian or Ladinian age for horizons above and below the basalts (Forsyth 1980). Tuffs near the top of the coal-bearing sequence near Bicheno in northeastern Tasmania have been dated at 214 ± 1 Ma (Bacon & Everard 1981, Bacon *et al.*, in Forsyth 1989), which places these beds within the Late Triassic according to the DNAG time-scale (Palmer 1983).

TRIASSIC DEPOSITIONAL ENVIRONMENTS

Although marine fossils occur in parts of the Permian sequence, no conclusive evidence of marine conditions has been reported in the Triassic sequence of Tasmania. Forsyth (1989) noted spinose acritarchs, but these could have been reworked. He also pointed out that sedimentary structures in some Middle Triassic rocks are similar to the deposits of tidally influenced estuaries. Trace fossils in the Upper Narrabeen Group of the Sydney basin suggest a marine influence in sandstones deposited under fluvially dominated estuarine conditions (Thann Naing, Macquarie University, written communication, 1989). Although similar trace fossils have not been reported in the Triassic of Tasmania, they could easily have been overlooked, as they were in the comparatively well-studied Sydney basin.

The predominance of channel-form sandstones and the occurrence of terrestrial vertebrate fossils (Cosgriff 1974, Camp & Banks 1978) in the Ross Formation suggest predominantly fluvial conditions. The multistorey nature of sandstone units and the paucity of fine-grained flood-plain deposits support the conclusion that these represent braided stream deposits. Local mudstone-dominated intervals have been interpreted as lacustrine and flood-plain deposits (Forsyth 1984, 1989). Lateral accretion surfaces, apparent in at least one outcrop in the upper Cluan Formation, highly variable palaeocurrent data, and a predominance of fine-grained beds suggest a meandering stream environment for the rest of the Triassic section. The generally fining-upward nature of the sequence is probably related to such factors as erosive lowering of the source area and the corresponding reduction in gradient, and a change to more humid conditions as indicated by the preservation of organic matter and coal.

PALAEOCURRENT DIRECTIONS

Palaeocurrent directions for 11 localities of the Ross Sandstone and its equivalents are shown in figure 4. A more complete listing of palaeocurrent data is shown in table 1.

The resistant Ross Sandstone is the only Triassic unit in which palaeocurrent data are easily gathered regionally. Dispersal directions are consistently toward the southeast quadrant except along the central east coast (Spring Beach, Schouten Island, Maria Island), where they swing toward the east. The low variability of directions at each locality and over the region is consistent with the interpretation that the Ross Sandstone represents low sinuosity braided stream deposits on a southeasterly dipping palaeoslope. Palaeocurrent directions in the reference section at Poatina are generally in the southeast quadrant throughout the Ross Sandstone, but show increasing variability upward as the sequence becomes finer grained. Readings from the overlying volcaniclastic upper Cluan, Tiers and Brady Formations vary greatly. Forsyth (1984)

FIG. 4 — Map of Tasmania showing palaeocurrent rosettes for the Ross Sandstone and equivalent units. Localities from E–W are: (1) Mt Rufus, (2) Mt Manfred, (3) Mt La Perouse, (4) Oatlands, (5) Poatina, (6) Mt Wellington, (7) Adventure Bay, (8) Prices Bay, (9) Spring Beach, (10) Maria Island, (11) Schouten Island. Compiled only for localities where data comprise 25 or more readings (see table 1). The rosette for the Oatlands locality (4) was reconstructed from data presented by Forsyth (1984). Palaeocurrent rosettes are comparative; the frequencies counts for each class interval (20°) are converted to percentages of the total data set and these values are used as the radii lengths of the sectors. Plots were made by "Sphere", as fig. 2.

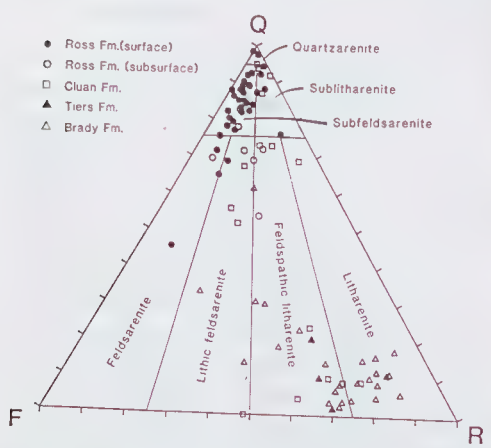

FIG. 5 — Triangular diagram showing compositional differences between formations (Folk et al. *1970).*

noted a reversal from southeast to northwest in palaeocurrent directions between the quartzose sequence and the overlying lithic sandstone sequence in the Midlands. Directions in equivalent rocks in the St Marys area are highly scattered and do not give a preferred direction (Turner & Calver 1987).

PETROGRAPHY

Modal analyses of the detrital component of 91 fine- to medium-grained sandstone samples are listed in tables 2 to 5. These are compared in the triangular diagram (fig. 5). Samples for point counting were selected from the more than 300 samples and thin sections from throughout the Tasmania Basin. As is apparent at outcrops, sandstones from the lower part of the Triassic section are very different in composition from those in the upper part of the section. This change occurs abruptly in the Poatina section within the Cluan Formation with the introduction of volcanic grains (fig. 6). Quartzose sandstones dominate the Ross and lower Cluan Formations and their stratigraphic equivalents. Sandstones in the Upper Cluan, Tiers, and Brady Formations and their stratigraphic equivalents contain many of the same types of grains, which are, however, overwhelmed by the volcaniclastic component. Quartzose sandstones occur rarely in the upper sequence and are easily differentiated from those in the lower sequence by the presence of volcanic lithic grains.

Ross and Lower Cluan Formations and Equivalents (Quartzose Sequence)

The quartzose sandstones of the Ross and Cluan Formations and their equivalents are characterised by low ratios of plagioclase to total feldspar (P/F), polycrystalline quartz to total quartz (Qp/Q) and volcanic lithic fragments to total rock fragments (V/R). The average composition of sandstones in the Ross Formation and its equivalents (table 2) falls into the subfeldsarenite field in the classification of Folk *et al.* (1970). As is apparent on the triangular plot (fig. 5), subsurface samples contain a higher percentage of feldspar and rock fragments and fall into the lithic feldsarenite field. These components apparently have been removed by weathering. The average compositions of subsurface samples from the Ross and lower Cluan Formations are not significantly different, but they fall into different fields, lithic feldsarenite and feldspathic litharenite.

TABLE 1
Palaeocurrent Data from Tasmania

Locality*	Formation	Age	N	VM	VS	SD
Poatina	Cluan	L Triassic	50	56†	20	90
Poatina	Ross	L Triassic	102	122	74	45
Mt Manfred	Ossa	L Triassic	33	117	82	37
Mt Rufus	Ossa	L Triassic	53	118	56	63
Woods Quoin	Ross	L Triassic	18	113	88	31
New Norfolk	Ross	L Triassic	20	139	45	80
York Plains	"Volc. lithic"	U Triassic	23	8†	22	91
Schouten Is.	Ross	L Triassic	53	102	74	46
Spring Beach	Ross	L Triassic	32	82	69	52
Maria Is.	Ross	L Triassic	32	85	81	37
Mt Wellington	Springs	L Triassic	63	116	56	63
Prices Bay	Ross	L Triassic	56	127	74	48
Adventure Bay	Ross	L Triassic	29	102	90	26
Mt La Perouse	"La Perouse"	L Triassic	59	114	64	34

N = number of readings, VM = vector mean in degrees, VS = vector strength in percent, SD = azimuth standard deviation in degrees.
* Localities shown on figure 1, except for Woods Quoin, New Norfolk and York Plains, which are in the Midlands area. † Not a meaningful direction.

Monocrystalline quartz grains are mostly subrounded to subangular and equant. Two-thirds are nonundulose. Included are (1) euhedral biotite or muscovite, (2) disseminated, randomly oriented rutile needles, (3) stubby light-green apatite, (4) rounded vacuole-shaped or euhedral tourmaline, and (5) euhedral zircon. Non-mineral inclusions include common curvilinear vacuole trains and abundant disseminated vacuoles. Some monocrystalline quartz grains with abundant vacuole inclusions also have vermicular chlorite inclusions; these grains are presumably of vein origin.

Polycrystalline quartz grains display elongated original crystals that have polyhedral outlines, smooth crystal–crystal boundaries, and many show interfacial angles of 120° at triple junctions of crystal unit boundaries. Elongate polycrystalline quartz grains are subangular to angular, whereas equant grains are more commonly subrounded to well rounded. Mineral inclusions are less abundant than in monocrystalline grains and are primarily randomly oriented muscovite or biotite.

Feldspar grains include microcline and orthoclase. Plagioclase grains are typically sodic andesine (An_{30-40}). One-third or fewer of all plagioclase grains are Carlsbad-twinned. They are commonly subrounded. No zoned grains were observed.

Rock fragments, in order of decreasing relative abundance, include: (1) sedimentary-metasedimentary grains, and subordinate (2) volcanic-hypabyssal, (3) metamorphic, and (4) plutonic varieties. Sedimentary rock fragments are subrounded to well-rounded mudstone and siltstone of intrabasinal origin, and slate. Only a few volcanic rock fragments were identified and none were vitric; these were probably derived from older volcanic rocks. Metamorphic rock fragments are low in relative abundance, but are ubiquitous. Most common are schistose polycrystalline quartz grains composed of elongate original host crystals with crenulated and sutured crystal–crystal boundaries; muscovite, biotite, or chlorite inclusions are oriented parallel or subparallel to the long axes of quartz grains. Plutonic rock fragments are rare and identified by micrographic or myrmekitic textures.

Minor constituents include mica concentrated on bedding planes. Biotite is more common than muscovite. The more abundant heavy minerals are angular, isotropic garnet and well-rounded to subrounded tourmaline grains that are pleochroic in green, dark blue, brown and zoned green-brown. Other heavy minerals include well-rounded or euhedral zircon, zoisite, clinozoisite and subrounded magnetite-ilmenite grains.

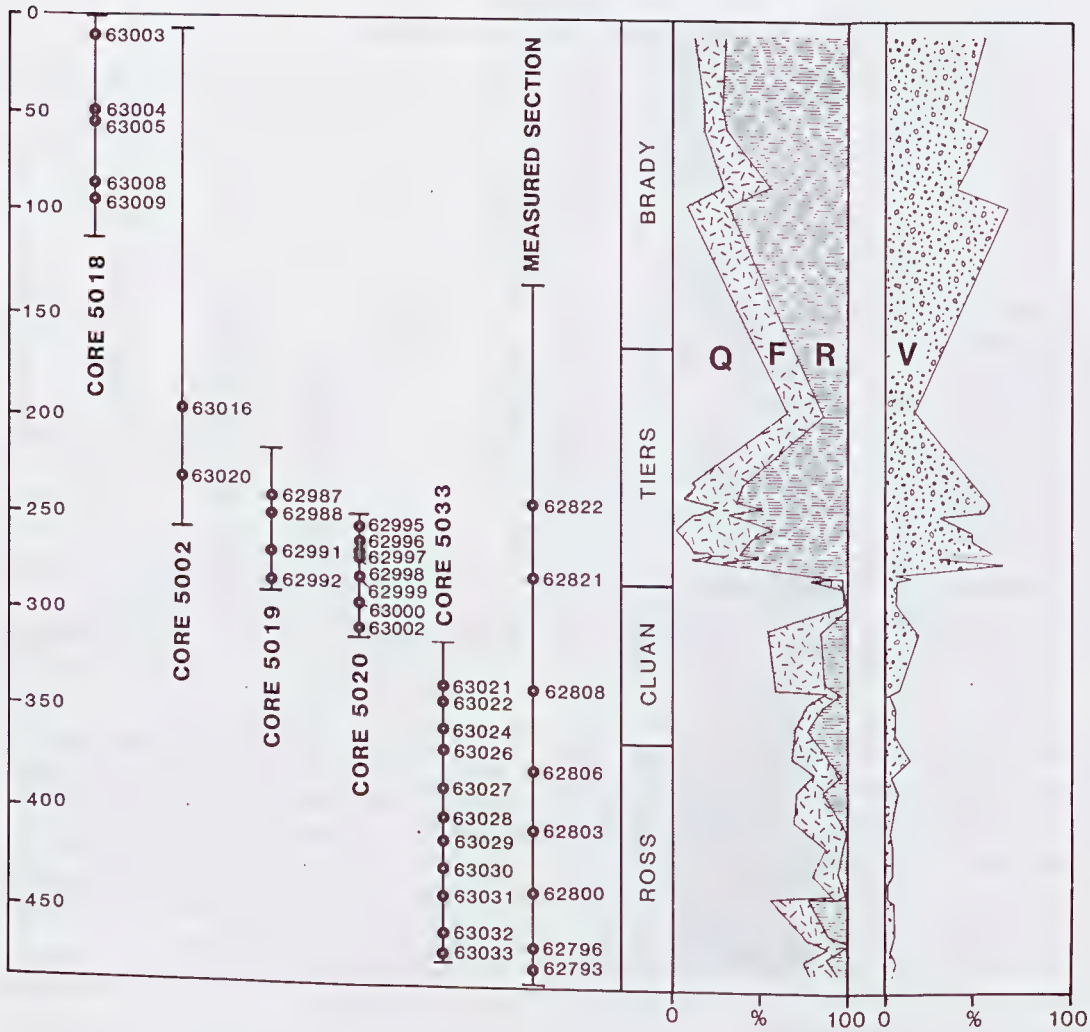

FIG. 6 — Graphic presentation of modal analyses of Poatina cores and measured section, showing percentages of quartz (Q), feldspar (F) and rock fragments (R) in column on left and percentage of volcanic (V) rock fragments compared to total rock fragments in column on right. Sample numbers refer to the collections of the Department of Geology, University of Tasmania.

Matrix and cement include small amounts of clay (2–3%), particularly in core samples. Clay cement consists of illite, kaolinite and minor chlorite and smectite and occurs as (1) recrystallised detrital mudstone fragments and clay matrix, (2) rims on detrital grains, (3) pore-lining and pore-filling cement, (4) feldspar grain replacements. Calcite occurs locally as anhedral intergranular pore-lining cement and as a feldspar and quartz grain replacement.

Upper Cluan, Tiers, Brady Formation and Equivalents (Volcaniclastic Sequence)

Volcaniclastic sandstones are characterised by abundant volcanic rock fragments. In contrast to the underlying quartzose sequence, volcaniclastic sandstones have high ratios of plagioclase to total feldspar (P/F), volcanic rock fragments to total rock fragments (V/R), and polycrystalline quartz to total quartz (Qp/Q)). The average compositions of the

TABLE 2
Modal Analyses of Ross Sandstone and Equivalent Units*

Locality	Sample	Formation	Classification	Q	F	R	P/F	V/R	Qp/Q
				(expressed as % of framework grains)			(expressed as ratios)		
Mt Rufus	62785	Ossa	Subfeldsarenite	89.3	7.0	3.7	0.33	0.27	0.04
Mt Rufus	62784	Ossa	Subfeldsarenite	78.2	17.5	4.3	0.11	0.61	0.05
Mt Rufus	62783	Ossa	Subfeldsarenite	82.0	12.3	5.7	0.08	0.23	0.11
Mt Rufus	62782	Ossa	Subfeldsarenite	86.3	12.0	1.7	0.25	0.80	0.05
Mt Rufus	62781	Ossa	Subfeldsarenite	80.3	16.0	3.7	0.14	0.27	0.04
Mt Rufus	62788	Ossa	Lithic feldsarenite	68.7	22.0	9.3	0.42	0.17	0.05
Mt La Perouse	62764	La Perouse	Subfeldsarenite	84.4	10.0	5.6	0.16	0.82	0.01
Mt La Perouse	62761	La Perouse	Subfeldsarenite	92.0	6.0	2.0	0.66	0.15	0.01
Mt La Perouse	62760	La Perouse	Subfeldsarenite	88.0	9.7	2.3	0.20	0.85	0.01
Mt La Perouse	62759	La Perouse	Subfeldsarenite	88.3	9.0	2.7	0.18	0.62	0.04
Mt La Perouse	62773	La Perouse	Subfeldsarenite	83.3	11.7	5.0	0.85	0.46	0.13
Scouten Is.	62881	Unnamed	Sublitharenite	76.1	5.7	18.2	0.52	0.42	0.00
Schouten Is.	62887	Unnamed	Quartzarenite	97.6	0.8	1.6	0.50	1.00	0.08
Schouten Is.	62890	Unnamed	Subfeldsarenite	85.2	11.4	3.4	0.00	0.40	0.08
Schouten Is.	62894	Unnamed	Quartzarenite	98.5	1.5	0.0	0.00	0.00	0.00
Mt Manfred	62857	Ossa	Subfeldsarenite	87.9	11.7	0.4	0.09	0.00	0.10
Mt Manfred	62589	Ossa	Subfeldsarenite	92.6	4.7	2.7	0.09	0.00	0.03
Mt Manfred	62860	Ossa	Feldsarenite	45.4	46.8	7.8	0.50	0.43	0.08
Mt Manfred	62862	Ossa	Subfeldsarenite	82.2	15.4	2.4	0.24	0.00	0.38
Midway point	62856	Knocklofty	Feldsarenite	71.5	23.2	5.3	0.13	0.21	0.04
Mt Knocklofty	62973	Knocklofty	Subfeldsarenite	82.4	10.3	7.3	0.45	0.13	0.06
Mt Knocklofty	62972	Knocklofty	Sublitharenite	87.2	6.0	6.7	0.44	0.10	0.03
Mt Knocklofty	62971	Knocklofty	Sublitharenite	92.3	2.7	5.0	0.75	0.40	0.04
Mt Knocklofty	62969	Knocklofty	Subfeldsarenite	85.0	10.3	4.7	0.74	0.35	0.07
Mt Knocklofty	62966	Knocklofty	Subfeldsarenite	87.3	9.4	3.4	0.50	0.11	0.02
Mt Knocklofty	62965	Knocklofty	Lithic feldsar.	65.0	25.9	9.1	0.57	0.16	0.06
Mt Wellington	62945	Springs	Sublitharenite	94.4	1.0	4.6	0.00	0.07	0.04
Mt Wellington	62944	Springs	Subfeldsarenite	84.0	8.7	7.3	0.23	0.36	0.04
Mt Wellington	62943	Springs	Sublitharenite	87.3	6.0	6.7	0.11	0.10	0.06
Mt Wellington	62942	Springs	Sublitharenite	88.3	3.7	8.0	0.36	0.08	0.02
Mt Wellington	62941	Springs	Subfeldsarenite	90.3	7.7	2.0	0.65	0.83	0.04
Poatina	62806	Ross	Subfeldsarenite	79.4	15.6	5.0	0.04	0.27	0.06
Poatina	62803	Ross	Subfeldsarenite	75.8	20.2	4.0	0.20	0.25	0.04
Poatina	62800	Ross	Subfeldsarenite	89.1	7.0	3.9	0.23	0.17	0.09
Poatina	62796	Ross	Subfeldsarenite	89.1	8.6	2.3	0.23	0.43	0.04
Poatina	62793	Ross	Subfeldsarenite	77.1	16.3	6.6	0.32	0.25	0.07
Poatina core	63027	Ross	Lithic feldsarenite	69.0	15.7	15.3	0.46	0.47	0.11
Poatina core	63028	Ross	Feldsarenite	69.4	25.3	5.3	0.36	0.43	0.10
Poatina core	63029	Ross	Subfeldsarenite	82.7	12.3	5.0	0.32	0.66	0.08
Poatina core	63030	Ross	Subfeldsarenite	78.0	15.0	7.0	0.57	0.42	0.18
Poatina core	63031	Ross	Feldsp. litharenite	54.0	21.7	24.3	0.60	0.21	0.14
Poatina core	63032	Ross	Lithic feldsarenite	71.6	16.7	11.7	0.78	0.22	0.33
Poatina core	63033	Ross	Feldsp. litharenite	72.0	12.0	16.0	0.83	0.39	0.21
Average of surface samples			Subfeldsarenite	84.2	11.2	4.6	0.27	0.36	0.06
Average of subsurface samples			Lithic feldsarenite	71.0	17.0	12.1	0.56	0.40	0.16
Average of all samples			Subfeldsarenite	81.6	12.4	6.0	0.32	0.34	0.08

Q = quartz, F = feldspar, R = rock fragment, P/F = plagioclase/total feldspar, V/R = volcanic rock fragment/total rock fragment, Qp/Q = polycrystalline/total quartz.
* Based on 300 or more data points for each sample.

TABLE 3
Modal Analyses of Cluan Formation*

Locality	Sample	Formation	Classification	Q	F	R	P/F	V/R	Qp/Q
				(expressed as % of framework grains)			(expressed as ratios)		
Poatina	62808	Cluan	Sublitharenite	87.2	4.9	8.0	0.27	0.12	0.06
Poatina core	62999	Cluan	Feldsp. litharenite	73.1	12.3	14.6	0.13	0.75	0.09
Poatina core	62992	Cluan	Sublitharenite	92.0	0.6	7.4	0.00	0.13	0.04
Poatina core	63000	Cluan	Quartzarenite	95.0	2.3	2.7	0.14	0.75	0.04
Poatina core	63002	Cluan	Lithic arkose	52.0	27.7	20.3	0.53	0.72	0.23
Poatina core	63021	Cluan	Lithic arkose	56.0	27.3	16.7	0.61	0.26	0.17
Poatina core	63022	Cluan	Feldsp. litharenite	73.0	9.3	17.7	0.50	0.32	0.11
Poatina core	63024	Cluan	Litharenite	69.0	4.7	26.3	0.50	0.22	0.14
Poatina core	63026	Cluan	Lithic arkose	67.3	18.7	13.9	0.27	0.82	0.17
Average composition				73.8	12.0	14.2	0.33	0.45	0.12

* Abbreviations and explanations as table 2.

upper and lower Cluan Formation (table 3) both fall into the feldspathic litharenite field, but they are generally at opposite ends (fig. 5). The average compositions of the Tiers and Brady sandstones (table 4) falls into the litharenite field. Surface and core samples are not significantly different.

Rock fragments are dominated by epiclastic volcanic-hypabyssal grains. These are equant or elongate and subangular to well rounded, with a few angular grains. Grains are intermediate to felsic in composition and are identified by microlitic plagioclase feldspar inclusions that result in felted and pilotaxitic textures. Plagioclase feldspar microlites occur in a light to dark-brown or brown-green matrix. The matrix is in some cases devitrified, chloritised or oxidised. Aphanitic fragments that have relict fabrics resembling those of feldspar microlites in devitrified glass groundmass were identified as volcanic fragments. Dark-brown fragments of vitric crystalline tuffaceous material occur sparsely, and are recognised by bubble-wall textures characteristic of volcanic glass shards. Basaltic fragments are associated with Triassic basalt flows in the Mt Nicholas Coal Measures north of St Marys. Other rock fragments include small but consistent proportion of schistose grains containing biotite, muscovite, or chlorite. Plutonic grains, typically with intergrowths of monocrystalline quartz with orthoclase, plagioclase, or microcline, are sparse but more abundant than in the underlying quartzose sequence.

Feldspars are dominated by plagioclase, ranging in composition from calcic oligoclase to sodic andesine (An_{35}). These are equant to elongate and angular to subrounded. The grains are typically fresh, but some contain vacuoles. Many grains show albite twinning, and about one-third of these display Carlsbad twinning as well. Many display well-developed oscillatory zoning. Microcline, orthoclase and microperthite occur in relatively minor amounts.

Quartz grains occur in relatively low abundance in most samples from the Tiers Formation and equivalents. A notable difference is the presence of angular to subrounded volcanic quartz grains. These exhibit straight extinction, display bipyramidal cross-sections, and some are embayed.

Minor constituents make up less than 1% of total framework grains. Of these, biotite is the most abundant, occurring mainly along bedding planes and cross-bedding laminae.

Matrix and cement comprise clay matrix (typically about 5%), calcite and clay cements, and less commonly laumontite and quartz. Calcite occurs extensively as an anhedral intergranular pore-filling cement and as a replacement mineral in plagioclase, quartz and volcanic rock fragments. Clay cements consist of chlorite and smectite with subordinate amounts of illite and kaolinite. Clay cement abundances are the opposite of those in the underlying quartzose sequence. Clay cements occur as (1) pore-lining, (2) hydration rims on plagioclase grains and volcanic lithic fragments, and (3) grain replacements. Authigenic quartz is present

TABLE 4
Modal Analyses of Tiers and Brady Formation and Equivalent Units*

Locality	Sample	Formation	Classification	Q	F	R	P/F	V/R	Qp/Q
				(expressed as % of framework grains)			(expressed as ratios)		
St Marys	62848	Mt Nicholas	Litharenite	15.5	15.2	69.3	0.81	0.71	0.12
St Marys	62847	Mt Nicholas	Litharenite	16.4	11.6	71.9	0.58	0.78	0.29
St Marys	62846	Mt Nicholas	Feldspathic litharenite	4.0	25.7	70.3	0.85	0.82	0.08
St Marys	62845	Mt Nicholas	Feldspathic litharenite	2.7	27.0	70.3	0.96	0.89	0.25
St Marys	62844	Mt Nicholas	Feldspathic litharenite	3.7	29.0	67.3	0.91	0.68	0.09
St Marys	62843	Mt Nicholas	Feldspathic litharenite	30.9	33.6	35.5	0.72	0.65	0.03
St Marys	62841	Mt Nicholas	Feldspathic litharenite	30.3	31.7	38.0	0.93	0.61	0.02
St Marys	62839	Mt Nicholas	Feldspathic litharenite	18.7	34.0	47.3	0.96	0.66	0.08
St Marys	62838	Mt Nicholas	Litharenite	9.3	19.3	71.3	1.00	0.65	0.14
St Marys	62837	Mt Nicholas	Feldspathic litharenite	14.4	24.7	60.9	0.98	0.86	0.09
St Marys	62836	Mt Nicholas	Litharenite	10.6	15.9	73.5	1.00	0.92	0.03
St Marys	62833	Mt Nicholas	Lithic feldsarenite	33.3	45.7	21.0	0.92	0.93	0.14
St Marys	62831	Mt Nicholas	Feldspathic litharenite	14.3	44.3	41.3	0.99	0.95	0.01
St Marys	62829	Mt Nicholas	Litharenite	5.3	16.9	77.8	0.98	0.99	0.31
Hobart	62939	New Town	Litharenite	6.3	10.6	83.1	0.71	0.62	0.36
Hobart	62938	New Town	Feldspathic litharenite	8.7	24.0	67.3	0.85	0.96	0.19
Hobart	62937	New Town	Feldspathic litharenite	7.0	25.9	67.1	0.91	0.74	0.19
Schouten Is.	62883	Unnamed	Litharenite	11.5	11.2	77.2	0.94	0.81	0.69
Schouten Is.	62884	Unnamed	Litharenite	18.0	6.2	75.7	1.00	0.66	0.25
Poatina core	63003	Brady	Litharenite	9.0	14.7	76.3	0.65	0.65	0.37
Poatina core	63004	Brady	Litharenite	11.8	10.5	77.7	0.80	0.48	0.47
Poatina core	63005	Brady	Litharenite	12.3	13.4	74.3	0.81	0.70	0.38
Poatina core	63008	Brady	Feldspathic litharenite	23.3	26.7	50.2	0.53	0.65	0.16
Poatina core	63009	Brady	Litharenite	4.5	23.3	72.4	0.72	0.86	0.07
Poatina core	63016	Tiers	Feldspathic litharenite	61.6	19.2	19.2	0.62	0.58	0.17
Poatina	62822	Tiers	Feldspathic litharenite	20.9	24.8	54.2	0.87	0.78	0.14
Poatina core	63020	Tiers	Feldspathic litharenite	10.4	28.2	61.4	0.69	0.75	0.35
Poatina core	62987	Tiers	Feldspathic litharenite	2.1	29.0	68.9	0.74	0.81	0.16
Average for Brady and equivalents			Litharenite	13.4	22.5	64.1	0.85	0.76	0.20
Average for Tiers			Feldspathic litharenite	11.1	27.3	61.5	0.77	0.78	0.22

* Abbreviations and explanations as table 2.

in minor amounts as a pore-filling cement. Laumontite occurs as pore-filling cement and grain replacements of plagioclase and volcanic rock fragments.

PROVENANCE

Quartz grains, heavy minerals, the predominance of potassium feldspar, and paucity of volcanic rock fragments in Lower Triassic sandstones suggest a varied source of plutonic, metamorphic, and sedimentary rocks. Palaeocurrent dispersal (fig. 4) and coarsening of sandstones toward the northwest in the Mt Manfred and Mt Rufus sections suggest a source area in the northwest where a variety of suitable Precambrian and lower Palaeozoic basement rocks are exposed.

The predominance of intermediate to silicic volcanic grains in the Middle and Upper Triassic sequence and the occurrence of silicic tuffs in northeastern Tasmania (Bacon *et al.*, in Clarke & Forsyth 1989) suggest the possibility of an active volcanic source, probably to the east. Palaeocurrent data do not show any obvious trends, but the possible reversal described by Forsyth (1984) in

TABLE 5
Similarities in the Upper Palaeozoic–Early Mesozoic Geology of Tasmania and Victoria Land*

(1)	Trough-shaped basins, probably of fault origin.
(2)	Late Carboniferous glacials rest unconformably above early Palaeozoic granites or folded and metamorphosed sedimentary rocks with great relief locally.
(3)	Sedimentary cycle began in Late Carboniferous with glacials and ended in Jurassic with tholeiitic vulcanism.
(4)	Coal measures in Permian and Middle to Upper Triassic.
(5)	Lower Triassic dominated by quartzose sandstone with little volcanic contribution.
(6)	Middle and Upper Triassic dominated by volcaniclastic sandstone.
(7)	Lower Triassic deposited by braided streams.
(8)	Middle and Upper Triassic deposited in part by meandering streams.
(9)	Jurassic intrusion of dolerite and extrusion of tholeiitic basalt.

* Tasmanian relationships are summarised in Clarke & Forsyth (1989) and antarctic relations in Collinson *et al.* (1986, 1987).

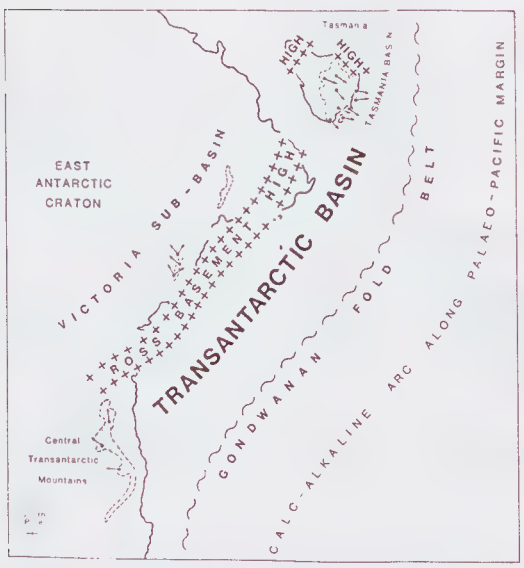

FIG. 7 — Map of palaeo-Pacific margin of the Gondwanan supercontinent including the Ross Sea coastline of East Antarctica and Tasmania. Positions of hypothetical tectonic features are based mainly on sedimentary evidence. Arrows indicate Early Triassic palaeocurrent directions. For Antarctica these are derived from information in Barrett & Kohn (1975), Barrett & Fitzgerald (1985), Barrett (1968), Collinson & Elliot (1984), Collinson et al. *(1983) and unpublished field data of the authors.*

the Midlands supports the existence of an easterly source. Basaltic grains in sandstones associated with basaltic lava flows in the Mt Nicholas Coal Measures near St Marys were locally derived.

Non-volcanogenic components of the upper volcaniclastic sequence suggest the continued presence of a basement source. Large clasts in the southeast and in the Midlands (Forsyth 1984, Clarke & Forsyth 1989), including quartz feldspar porphyry and lithics containing Permian fossils, suggest a new source area to the east. Basement uplift occurred in the Late Permian or Early Triassic in northeastern Tasmania (St Marys section, fig. 3) where the uppermost Permian and Lower Triassic are missing along a disconformity (Forsyth 1989).

PALAEOGEOGRAPHY

In most Gondwanan reconstructions (e.g. DeWitt *et al.* 1988), Tasmania is off the Victoria Land coast, in line with the Transantarctic Mountains (fig. 7). The Transantarctic basin, which paralleled the Transantarctic Mountains, consisted of an intracratonic sub-basin in Victoria Land and a foreland basin that were separated at times by basement highs. Evidence for a foreland basin is based on palaeocurrent dispersal and provenance relationships in the Central Transantarctic Mountains, and an intensely folded sedimentary sequence in West Antarctica (Collinson *et al.* 1981, Vavra *et al.* 1981, Collinson 1990a). The hypothetical Ross basement high blocked drainage into the Victoria sub-basin

until Middle Triassic, when volcaniclastic sediment from a volcanic arc along the palaeo-Pacific margin spilled over the high.

A major problem in interpreting and comparing the Tasmania and Transantarctic basins is that the present extent of Triassic outcrops represents only a fraction of their original distribution (fig. 7). If these outcrops are part of a larger Transantarctic–Tasmania basin, they should have similar geologic histories and fit into an overall basin model. Anyone who has studied these rocks in both regions is struck by their similarity (table 5).

The Permian in Tasmania, except for the presence of coal measures, is different from that of Victoria Land. The marine cycles that contain an abundant shelly fauna in Tasmania are unknown in Antarctica. If these two regions are part of the same basin, Tasmania occupied the marine end of a basin that emptied into the palaeo-Pacific Ocean.

Triassic correlations between Antarctica and Tasmania are shown in figure 8. The correlatives of the Ross and Cluan in the Transantarctic Mountains are the Feather Conglomerate and lower part of the Fremouw Formation, both of which are prominent cliff-forming, quartzose, braided stream deposits (Barrett & Kohn 1975, Barrett & Fitzgerald 1985, Collinson 1990b). These formations overlie Permian coal measures along a prominent erosion surface. Palaeocurrents suggest that streams flowed northward toward the Tasmania Basin (Collinson *et al.* 1987). The Tiers and Brady Formations are similar to the volcaniclastic upper part of the Fremouw and Falla Formations in the central Transantarctic Mountains, and the Lashly and Section Peak Formations in Victoria Land. These units contain coal or carbonaceous shale. Palaeocurrents remain northward toward the Tasmania Basin, but a transition occurs from braided streams in the upper part of the basin to meandering streams in the lower part of the basin toward Tasmania (Collinson *et al.* 1987).

The hypothetical Transantarctic–Tasmania basin was similar in size and many features to the Sydney–Bowen basin, which was also occupied by an extensive river system during the Triassic, and is classified as a foreland basin (Conaghan *et al.* 1982, Veevers *et al.* 1984). The Sydney–Bowen basin is bordered by the craton to the west, which contributed quartzose sandstone from the erosion of Devonian sandstones and metamorphic and granitic rocks of the Lachlan fold belt. On the east the active New England orogen contributed primarily lithic sandstone with an important penecontemporaneous volcanic component. Major drainage was axial and emptied into the palaeo-Pacific ocean.

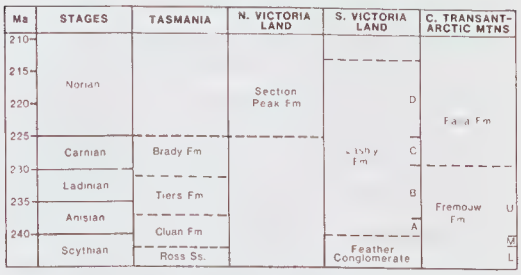

FIG. 8 — Time–stratigraphic chart comparing Tasmania to Antarctica. Based on DNAG time-scale (Palmer 1983).

Using the Sydney–Bowen basin as a model, the Tasmania basin is interpreted as being part of a much larger intracratonic basin that extended landward into the Victoria Land portion of East Antarctica. This basin was bounded to the west by the craton of East Antarctica and southeastern Australia. Precambrian to lower Palaeozoic rocks in the Ross and Tasman orogens on the palaeo-Pacific margin of the Gondwanan craton, including basement highs in Tasmania, were the major sources of quartzose sediment in the Permian and Early Triassic. A calcalkaline volcanic arc, which bordered the Gondwanan palaeo-Pacific margin from eastern Australia to West Antarctica, was the source of volcaniclastic sediment that flooded the basin in Middle Triassic time. Other than local uplift, there is no direct evidence of a fold belt comparable to the New England or West Antarctic orogens in Tasmania or Victoria Land. However, folding, thrusting and uplift of a volcaniclastic apron of sediment from the volcanic arc along the palaeo-Pacific margin would explain the sudden flood of volcaniclastic sediments into these regions.

CONCLUSIONS

The Triassic sequence of Tasmania, best represented by the continuous stratigraphic section at Poatina, consists of a lower quartzose sandstone (Ross and lower Cluan Formations) overlain by an upper volcaniclastic sandstone and mudstone (upper Cluan, Tiers and Brady Formations). The quartzose sequence was deposited by braided streams and the volcaniclastic sequence by meandering streams. Palaeocurrent dispersal in the quartzose sequence was toward the southeast and east. Present data are insufficient to establish palaeocurrent patterns for

the volcaniclastic sequence. The source area for the quartzose sequence was in northwestern Tasmania and the Gondwanan craton west of Tasmania. The primary source for the volcaniclastic sequence was a calcalkaline volcanic arc east of Tasmania along the palaeo-Pacific margin. The Triassic sequences in Tasmania and the Victoria Land sector of the Transantarctic Mountains are greatly similar, suggesting that they were once part of the same, but much larger basin. The Transantarctic–Tasmania basin was similar to the Sydney–Bowen basin in size, configuration, and history. They were both foreland basins that developed on the Gondwanan craton in front of a fold-thrust belt inside the calcalkaline volcanic arc that bordered the palaeo-Pacific margin.

ACKNOWLEDGEMENTS

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HUMAN EXPLOITATION OF THE SHORT-TAILED SHEARWATER (*PUFFINUS TENUIROSTRIS*)

by I.J. Skira

(with three tables and six text-figures)

SKIRA, I.J., 1990 (31:x): Human exploitation of the short-tailed shearwater (*Puffinus tenuirostris*). *Pap. Proc. R. Soc. Tasm.* 124(1): 77–90. ISSN 0080–4703. Department of Parks, Wildlife and Heritage, GPO Box 44A, Hobart, Tasmania, Australia 7001.

The short-tailed shearwater or Tasmanian muttonbird *Puffinus tenuirostris* (Temminck, 1835) breeds mainly in Tasmania, particularly on Bass Strait islands. In Tasmania it is a partly protected species, subject to annual open seasons.

Aboriginal exploitation of this species is shown by small amounts of material in several archaeological sites in Tasmania and the Australian mainland; such use was limited by seasonal, technological and cultural choice. Present-day Aboriginal Tasmanians view the muttonbirding industry as one of their major social and economic activities.

On the decline of the seal industry established by Europeans in Bass Strait, some sealers settled on the islands hunting game, farming and collecting shearwaters for their livelihood. Throughout the 19th and early 20th centuries, muttonbirding was the mainstay of the local economy, but in the last 60 years the industry has declined considerably, the annual catch falling from one million to about 300 000 chicks.

Key Words: shearwater, muttonbird, Bass Strait islands, Tasmania.

INTRODUCTION

The short-tailed shearwater *Puffinus tenuirostris* (Temminck, 1985), commonly known as the Tasmanian muttonbird, is one of about 100 species in the relatively small order Procellariiformes. This ancient order probably originated from groups of aquatic birds present at the end of the Cretaceous Period, some 65 million years ago (Brodkorb 1971), but the phylogenetic history of shearwaters is little known (Kuroda 1954). The short-tailed shearwater has not been found in any deposits apart from prehistoric archaeological sites (Bowdler 1984, Friedman 1934a,b, 1941, Vanderwal & Horton 1984).

This species is Australia's most abundant seabird and is also one of the most plentiful birds in the high Arctic during the boreal summer. It is linked to Aboriginal and European settlement in Tasmania, due to its importance as a source of food. In Tasmania at present it is a partly protected species, subject to annual open seasons. Commercial muttonbirders take chicks and sell their meat for human consumption, feathers for bedding and proventricular oil for medicinal and stock use; non-commercial or amateur muttonbirders take chicks for food only. Elsewhere in Australia, short-tailed shearwaters are fully protected and not harvested.

The chronology for this review falls into convenient periods. Exploitation is divided into before 1803, 1803–50, 1850–1930 and after 1930. In 1928 the *Animals and Birds Protection Act* was proclaimed. This regulated wildlife, including muttonbird hunting, until 1970.

BIOLOGY

Most information on the biology of short-tailed shearwaters has been obtained from studies on Fisher Island in the Furneaux Group (fig. 1). The small size of the island (1 ha) has enabled all birds to be banded and their lives followed since 1947 (Serventy 1967, 1974, 1977, Naarding 1981, Serventy & Curry 1984, Wooller *et al.* 1988).

The short-tailed shearwater is a circum-Pacific migrant, spending the boreal summer in the region of the Aleutian Islands. It has a precise breeding regime and first appears at breeding colonies about the third week of September. One egg is laid between 19 November and 2 December, the peak of egg-laying being 24–26 November every year. The incubation period is 53 days; the chicks hatch from mid-January onwards. The chick is in the burrow for about 94 days and reaches its maximum weight of approximately 800 g in early April (Lill & Baldwin 1983). Mean age at first breeding is six years. Mean life is 21 years, although birds can live for more than 36 years (author's observation). Annual mortality in adults is approximately 10% and at least 50% of chicks die before breeding.

The breeding range is restricted to eastern Australia, particularly Tasmania. There are 167 colonies known around the coast of Tasmania and

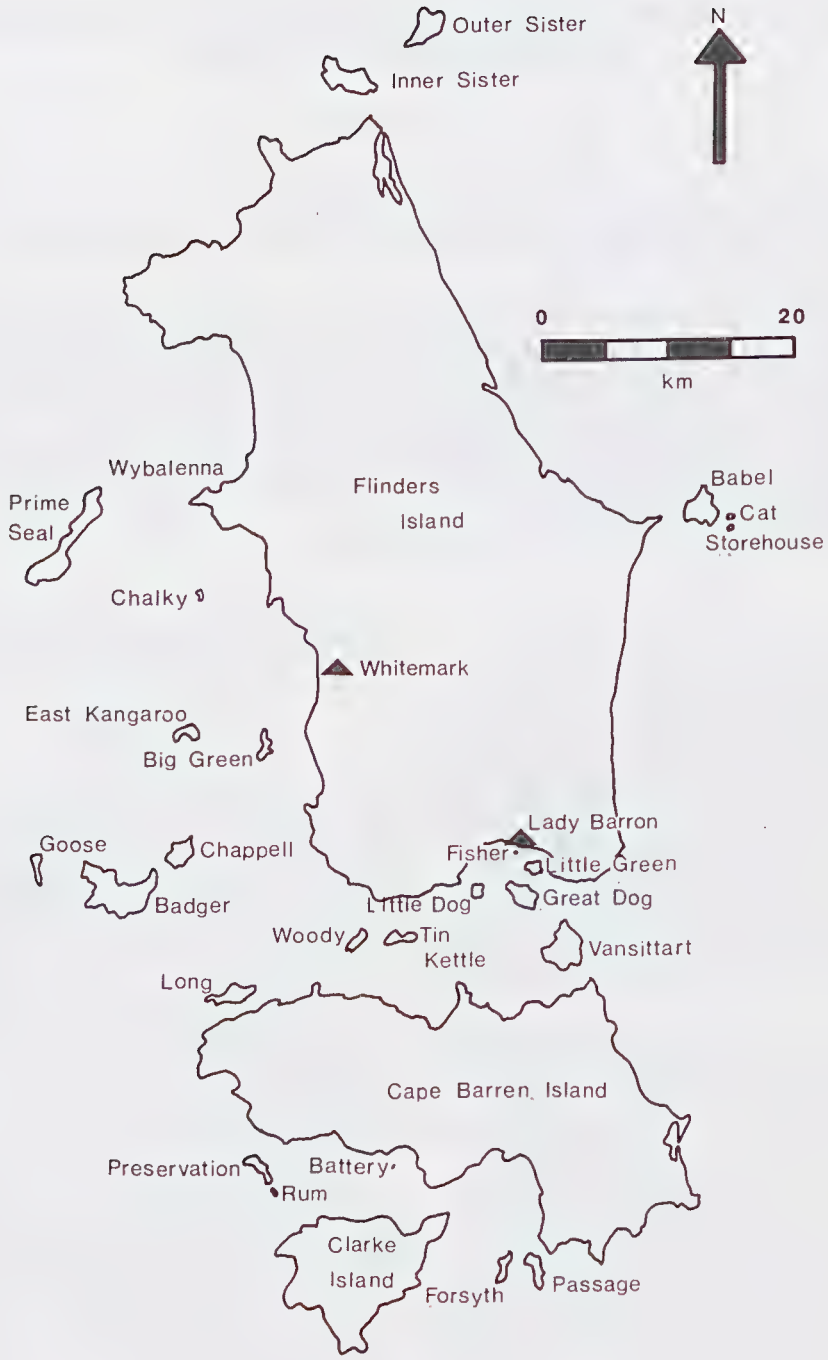

FIG. 1 — Location of place names in the Furneaux Group.

its near offshore islands (fig. 2); it is unlikely that many more colonies remain to be discovered. The total area of colonies is 1527 ha and the number of burrows is estimated at 11.4 million (Skira *et al.* 1986). The largest colony is on Babel Island with an estimated 2.86 million burrows (Towney & Skira 1985). In other Australian States, Victoria has 1.45 million burrows (Harris & Norman 1981), South Australia 1.25 million (A.C. Robinson, pers. comm.), New South Wales 25 700 breeding pairs (Lane 1979) and Western Australia 250 burrows (Lane 1983). Usually 80% of burrows contain eggs and, prior to the harvest season, approximately 50% of burrows contain chicks. The world breeding population of short-tailed shearwaters, based on a total 14.13 million burrows, is 11.3 million breeding pairs, 81% of which are in Tasmania.

EXPLOITATION BY HUMANS

Australia Pre-1803

The present-day Aboriginal population of Tasmania regard the muttonbird industry as one of their major social and economic activities. In this context, muttonbirding has been described as

> "... a traditional seasonal activity, with origins in the pre-history of Tasmania, which developed into an annual happening of significant importance to the Aboriginal communities in Tasmania." (*Tasm. Parl. Pap.* 94, 1978.)

Human occupation in Tasmania and its near offshore islands began about 30 000 years BP (southern Tasmania — Allen *et al.* 1988); later occupation occurred at Cave Bay cave, Hunter Island (23 000 years BP — Bowdler 1984). Ice age hunters in southwestern Tasmania, 20 000 years BP, were the most southerly humans on earth (Kiernan *et al.* 1983). At that time Tasmania was still connected to mainland Australia. The present coastline was formed 7000 to 6000 years ago (Jennings 1971). By the time of European contact, archaeological evidence suggests widespread Aboriginal occupation, with a total population of about 4000 divided among nine tribes.

According to Sutton & Marshall (1980), cultural adaptation by the Tasmanian Aborigines led to a type of settlement pattern and selective coastal hunting strategy similar to that found with Maoris in New Zealand and Morioris in the Chatham Islands. In all these regions, hunting strategies centred on the exploitation of fatty-meat resources (such as seals, albatrosses, petrels and penguins) at the time of year when they were most aggregated, easily taken and fattest. Tasmanian Aborigines did not preserve birds for future consumption, but used the meat immediately.

On the Australian mainland, Aborigines had limited access to shearwater colonies because the colonies were usually on remote, relatively inaccessible islands (Jones & Allen 1979). However, ethnohistorical accounts indicate that, during the early 19th century, some islands adjacent to Wilsons Promontory were visited by Aborigines hunting shearwaters (Smyth 1878, Coutts 1970).

Tasmanian Aborigines were hunter-gatherer people whose technology was elementary but adequate to enable successful adaptation to the wide range of environments in Tasmania. Their economy was marine-orientated for at least certain periods of the year, and the coast formed part of the habitat of every Tasmanian tribe at some stage of its seasonal movements (Jones 1977). They could cross to islands only by canoe/raft or, occasionally, by swimming (Jones 1976, Bowdler 1980). The watercraft were inadequate for reaching more distant islands such as the Furneaux Group and King Island (Jones 1977). Their diet included wallabies, and wombats, while remains of short-tailed shearwaters occur in archaeological sites on Hunter Island in northwestern Tasmania and on Maatsuyker Island and in Louisa Bay in southwestern Tasmania

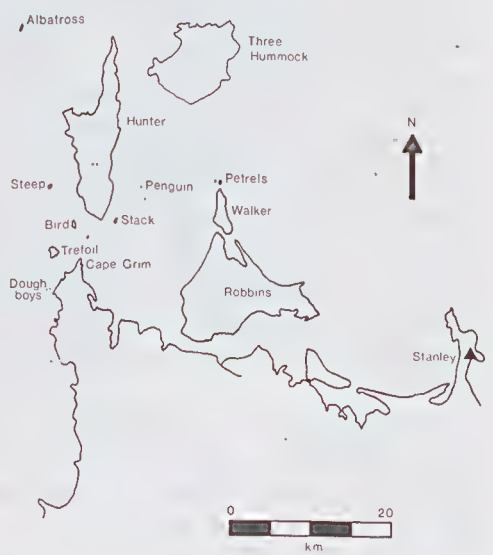

FIG. 2 — Location of place names in the Hunter Group.

(figs 2, 3). Those who lived along the northwestern and southwestern coasts relied on shellfish and foods such as seals, sea birds and land mammals that were available all year round, and land birds.

The level of exploitation of shearwaters at this time can only be guessed. The amount of material present in archaeological sites is typically small in quantity compared with other vertebrate remains (tables 1, 2). At Cave Bay cave on Hunter Island, estimated minimum numbers of short-tailed shearwaters were 67 compared to a total vertebrate faunal component of 4065 that also included 84 wallaby, 104 other medium-to-large marsupials and 2737 rodents (Bowdler 1984). At the nearby Stockyard site, shearwaters contributed 0.23% to the vertebrate fauna, based on body weight (O'Connor 1980). In southwestern Tasmania and Maatsuyker Island, the contribution of shearwaters to the total vertebrate fauna, based on body weights, varied from 1 to 6% (Vanderwal & Horton 1984); when invertebrates are included in the analysis, short-tailed shearwaters make up less than 1%.

The range of possible reasons for the lack of shearwater remains is varied. Perhaps other animals such as seals and wallabies were in greater abundance and more readily captured; perhaps shearwaters did not breed in the same locations or in the same numbers as now; perhaps the Aborigines did consume large numbers of these birds but either the evidence does not survive or sites with such evidence have not been investigated by archaeologists. Bowdler (1979) suggested that the return of shearwaters from their migration in September may have been the signal for Tasmanian Aborigines to go to Hunter Island to obtain seals and other foods. That is, the return of the birds was a signal rather than the principal objective. Gaughwin (1978) indicated that the utilisation of shearwaters was limited by seasonal, technological and probably cultural choice, i.e. preference for varied diet. Lack of knowledge of the prehistoric distribution of shearwater colonies means that interpretation of Aboriginal use of short-tailed shearwaters prior to 1803, based on their present distribution, could be unreliable or even grossly misleading.

European exploitation of short-tailed shearwaters began with the beaching of the *Sydney Cove* in February 1797 between Preservation and Rum Islands in the Furneaux Group. The crew landed safely on Preservation Island and erected their tents near shearwater burrows (Cumpston 1973). The birds and a daily allowance of a cupful of rice constituted a great part of their food during more than five months on the island (Flinders 1814).

Between 2 December 1797 and 25 February 1798, on his first exploratory journey into what was later named Bass Strait, George Bass and a party of six seamen subsisted to a large extent on shearwaters during their 900 km trip around the southeastern coast of mainland Australia. They salted birds for their provisions (*Hist. Rec. NSW*. III: 325). Flinders later (1801) described the shearwater's habitat of coming in "... from the sea in the evening in numbers that surprise a person unaccustomed to them."

Australia 1803–50

Tasmanian Aboriginal muttonbirding at the time of European settlement has been summarised by Gaughwin (1978) from the journals of George Augustus Robinson. Tasmanian Aborigines frequently went to the Hunter Group to collect muttonbirds but were reluctant to go when the birds were not present. Robinson was told they knew it was time to go to the islands when the lightwood tree (*Acacia melanoxylon*) flowered in early spring. According to him, they went from Cape Grim to Trefoil Island, Trefoil Island to Bird Island and Bird Island to Hunter Island (Plomley 1966).

Gaughwin (1978) noted that Tasmanian Aborigines were fond of adult birds, eggs and chicks as food; also muttonbird fat and red ochre were mixed together and smeared on their bodies. The birds were present for seven months but only on the islands and available to only a few tribes, principally those living in far northwestern Tasmania. The details of Aboriginal muttonbirding, however, are unclear as Robinson's journals were written thirty years after sealers had made contact with Tasmanian Aborigines.

Within a short period of European settlement of Tasmania in 1803, the Aboriginal population was reduced by a deliberate campaign of extermination and diseases associated with captivity (Ryan 1981). In 1831, the remaining Tasmanian Aborigines were mustered by George Augustus Robinson and settled at Wybalenna on Flinders Island under government supervision (Plomley 1987). While there, the Tasmanian Aborigines maintained their customs of muttonbirding, collecting birds and eggs during their season, mainly from Big Green Island, with smaller amounts from East Kangaroo, Chalky and Prime Seal Islands (Plomley 1987). Plomley described their internment at the settlement as a "weep in silence" in which the return of the birds was probably the highlight of each year's existence. Robinson arranged a type of economic system at

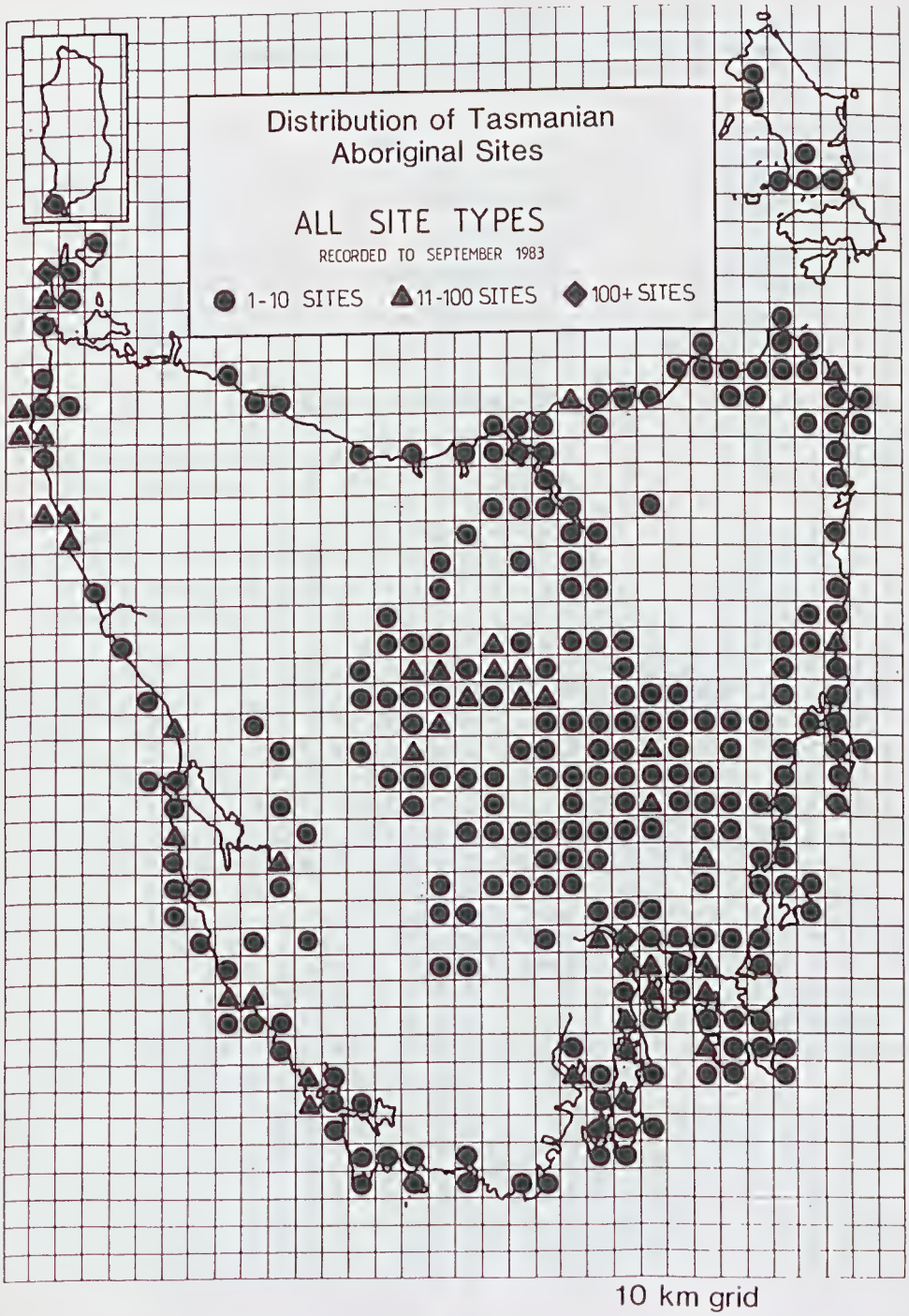

FIG. 3 - Distribution of all Tasmanian aboriginal site types recorded up to September 1983. (Source: Archaeological Section, Department of Parks, Wildlife & Heritage, Hobart, Tasmania.)

TABLE 1
Occurrence of Short-tailed Shearwaters (STSW) and Other Seabirds in Excavated Shell Middens in Tasmania

Site	Layer name	Date (BP) reference	Description
Cave Bay cave	Upper midden	990±90 to 2580±70 (Bowdler 1984)	10 STSW; 1 fairy penguin; 3 albatrosses; 65 other Procellariidae
	Sterile layer	3330±100 to 3960±110	25 STSW; 178 other Procellariidae
	Lower midden	3960±110 to 7180±90	27 STSW; 1 fairy penguin; 60 other Procellariidae
	Upper Pleistocene	6600 to <19 000	5 STSW; 16 other Procellariidae
	Lower Pleistocene	>19 000	3 other Procellariidae
Muttonbird midden		1000 (Bowdler 1979)	7 STSW; 1 fairy penguin
Rookery rockshelter		1370±70 (Bowdler 1979)	14 adult STSW and possibly 5 chicks; 3 other Procellariidae
Stockyard		760±70 (O'Connor 1980)	12 adult STSW; 1 fairy penguin; 1 white-capped albatross; 4 Australian pelicans; 11 diving petrels; 3 fairy prions; 5 black-faced cormorants; 1 Pacific gull
Little Duck Bay		800–1000 (Bowdler 1979)	7 STSW; 4 fairy penguin; 1 white-capped albatross; 1 cormorant
Louisa River 1		2970±200 (Vanderwal & Horton 1984)	27 STSW; 7 white-capped albatross; 42 fairy prions
Louisa River 2		2580±100 to 2830±155 (Vanderwal & Horton 1984)	9 STSW; 1 fairy penguin; 5 white-capped albatross; 6 fairy prions
Louisa River cave 1		No date (Vanderwal & Horton 1984)	4 STSW; 1 intermediate-sized penguin; 1 white-capped albatross; 1 fairy prion
Louisa River cave 2		870±90 (Vanderwal & Horton 1984)	28 STSW; 3 fairy penguin; 1 small albatross; 46 fairy prions; 1 diving petrel
Louisa Creek 1		1250±100 (Vanderwal & Horton 1984)	1 STSW
Maatsuyker Island		400±90 to 570±100 (Vanderwal & Horton 1984)	310 STSW; 4 fairy penguins; 10 white-capped albatross; 60 fairy prions
Tasman Island		Note date (Harris 1984)	STSW — possibly due to human occupation

TABLE 2
Occurrence of Short-tailed Shearwater (STSW) and Other Seabirds in Excavated Shell Middens on the Australian Mainland

Site	Date (BP) reference	Description
Captain Stevensons Point, Victoria	approx. 650±80 (Coutts *et al.* 1984)	4 *Puffinus* sp.; 6 albatross; 1 gannet
Burrill Lake, NSW	<1660 (Lampert 1971)	1 STSW
Currarong, NSW	1970±80 to 3740±100 (Lampert 1971)	21 STSW
Durras North, NSW	480±80 (Lampert 1966)	Numerous bone-points and unworked bone
Bass Point, NSW	Upper midden, 1379±150 (Bowdler 1970)	15 STSW, bone points
Seton, SA	10 940±160 to 16 110±110 (Hope *et al.* 1977)	1 *Puffinus* sp.

Wybalenna whereby for the sale of salted muttonbirds, wool, wallaby skins and their labour, Aborigines were given credits that they could exchange for items from the settlement. By 1847, only 45 Aborigines remained alive. The settlement at Wybalenna was closed and the survivors removed to Oyster Cove near Hobart (Ryan 1981).

The discovery of numerous seals in Bass Strait in the 18th century led to their exploitation in a short-lived industry. On its demise, European sealers began to settle permanently on islands in Franklin Sound and near Cape Barren Island. These small islands had many attractions of position and natural resources, especially the shearwaters, which could supply both subsistence and a cash crop (Murray-Smith 1973). With small farming, vegetable growing and some hunting (wallabies and seals) a diverse economic base was provided and the abundance of shearwaters, which were present for seven months of the year, gave the settlers a reliable, precise and seemingly endless resource to exploit.

The sealers took Aboriginal women from Tasmania and mainland Australia for wives. John Boultbee, an English adventurer who lived amongst them for several months in 1823, described the muttonbird as follows (Begg & Begg 1979):

> "a nourishing sort of food when eaten with potatoes, to such constitutions as those who are inured to a life of hardiness. At a certain time of the year they grow lean which is the best time for plucking the feathers and a black woman will pluck 500 birds per day for her work — the feathers are usually sold for flour, spirits, etc."

From the Furneaux Group Boultbee sailed to King Island and to islands off Victoria. Disgusted with his fellow companions, he tried a solitary existence on Phillip Island but eventually his lack of wilderness experience caused him to destroy a shearwater colony by fire (Begg & Begg 1979).

James Backhouse and his fellow Quaker missionary, George Walker, visited the Furneaux Group in 1832. In those days feathers were the main product obtained from adult birds; a method of catching the birds is described by Backhouse & Taylor (1862):

> "a pit is dug near the sea-shore, six or eight feet square, and half that depth. A hedge of shrubs or sticks is formed in two lines, enclosing a great number of the holes, and converging towards the pit. A similar hedge is erected on the far side of the pit to hide the view of the ocean. A few men take their stations at the end of the enclosure furthest from the excavation, and when the birds sally forth in the morning, they urge them onwards towards the pit. Being unable to hide among the grass and scrub that surrounds them, they tumble into the pit one after another, and are suffocated."

Preservation, Woody and Vansittart Islands were the principal homes for the Europeans, who had resided permanently in the area since about 1815. In about 1839, the price received for feathers was 3d a pound (Stokes 1846) but several years later only 2d a pound (Elwes 1854). Stokes noted that the cargo of two boats he saw consisted of 30 bags, each weighing nearly 30 pounds or "the spoil of 18 000 birds". Apart from feathers the European sealers collected adult birds to salt or smoke, eggs in November–December and fledglings for their oil and fat. The young birds were either salted after being plucked and cleaned or smoked and dried in the large chimneys of the huts (Broadfoot 1845). Occasionally huts were destroyed when the chimney or roof caught alight (*Launceston Examiner* 30 May 1899). The sealers sailed to Launceston two or three times a year to sell their goods at the markets and returned with stores for the next six months (Stokes 1846). The oil was sold in Launceston from 4s. to 4s.6d. a gallon (Elwes 1854) and mainly used in lamps. Later, as technology caught up with the 19th century, it was also used for machinery, railway engines and carriages, and medicinal purposes, while the fat was used for soap-making, in foundries for smelting, tanning and for machinery (*Launceston Examiner* 26 April 1892).

The first fifty years of the 19th century were a period of establishing permanency of occupation. Government interferences from Hobart came through Robinson, who wanted the Furneaux Group for Aboriginal settlement and all sealers to be deported. An Act was passed requiring sealers and others to depart the Straits (*6 William IV No. 15,* 1836, repealed by *26 Victoria No. 5,* 1863), but it had little influence on settlement of the islands.

Australia 1850–1930

During the 19th century and the early decades of the 20th century, muttonbirding was the mainstay for the Islanders. Other employment came from hunting wallabies, sealing, making shell necklaces, shearing sheep and gathering resin from grasstrees *Xanthorrhoea australis* for varnish. Occasionally whale strandings were utilised (Skira 1987). Initially most people went to Chappell Island with their goods, chattels, cats and dogs. Towards the early part of the 20th century, Babel Island became the focus of muttonbirding.

The season extended over a period of seven weeks and was a family affair. The men caught the birds, the children cut off wings and feet, and the women plucked, scalded and helped to open and pack the birds in brine. Muttonbirding was a very social occasion, an opportunity for families to renew friendships with other seldom-seen families. The strong social tradition continued even as late as the 1930's, when activities such as dances were still held on Saturday night on Great Dog Island during the season (Dorothy Cook, pers. comm.).

The subsistence life of the Islanders was a bush economy which Robinson & Ghostkeeper (1987) described as a livelihood reliant on renewable-resource gathering and harvesting. Such an economy results in a strong relationship between human social groups and their resource base (Usher & Wenzel 1987), in this case shearwaters and wallabies. Work, leisure, family life and living become intertwined into cohesive whole which, according to Robinson & Ghostkeeper (1987), tends to be information rich and mass poor. Other features of people involved in a bush economy are that the household unit is generally more stable over time and endures for many years. The Islander community of Bass Strait exemplifies these features, for it lasted well over 100 years and the social differences between it and other Tasmanians always made the Islanders conspicuous, surviving all attempts to make its people conform to the 'norm'.

The number of Aboriginal Tasmanians living on the Furneaux Islands through the century is difficult to establish. Broadfoot (1845) said, in June 1844, there were five to six huts and 15 to 16 people on Woody Island. In September 1849, Elwes (1854) counted six houses, six adults and four children on Vansittart Island. The total population was probably not more than 50 to 60 during the 1850's. In 1870, 84 or 35% of the total population were Aboriginal Tasmanians (table 3). This percentage was the highest ever achieved and was only approached in 1933, a decade to be recalled later as the "good times" (Ryan 1981). The main occupations of Aboriginal Tasmanians living on Cape Barren Island early in the 20th century were labouring and hunting, including muttonbird harvesting (fig. 4). For example, hunters constituted 42% of the work-force on Cape Barren Island in 1909. Labouring soon became the main occupation, although census data show that trapping was still important in the 1920's. Other occupations were boat-building, carpentering, mining, farming, while all women did domestic or home duties. These occupations were temporarily suspended during the muttonbird season, when everyone joined in the harvest. Later on, from the 1930's, most people depended on government handouts for year round support so muttonbirding must have given them some

TABLE 3
Population Statistics for the Furneaux Group

Year*	Population		Total	Aborigines		Population 20+ years	
	Male	Female		Male	Female	Male	Female
1870	138	104	242	84		59	49
1881	137	115	252	–	–	–	–
1901	–	–	–	79	78	–	–
1911	366	250	616	–	–	215	111
1921	522	383	905	82	68	289	231
1933	567	436	1003	139	112	328	224
1947	471	382	853	105	76	297	223
1954	574	453	1027	–	–	347	243
1961	814	593	1407	–	–	460	298
1966	703	531	1234	–	–	417	285
1971	533	435	968	–	–	340	279
1976	509	448	957	–	–	342	288
1981	538	501	1039	–	–	351	315
1986	521	489	1010	45	49	355	335

* Sources: 1870–1901, *Tas. Parl. Paps.*; 1911–86, Australian Bureau of Statistics.

independence and extra cash to buy things which otherwise were out of reach.

The best accounts we have of this unique Islander community are from the writings of Church of England missionaries such as Nixon (1857), Reibey (*Tasm. Parl. Pap.* 17. Legislative Council 1862 Letter from the Venerable Archdeacon Reibey, on the subject of the half-caste islanders in the Straits; *Tasm. Parl. Pap.* 48. Legislative Council 1863 Half-caste islanders in Bass's Straits Report of the Ven. Archdeacon Reibey), Montgomery (Ryan 1981; Hart 1963) and, in particular, Cannon Marcus Brownrigg who visited the islands on 13 occasions between 1872 and 1885 (Murray-Smith 1979). Bishop Nixon had nothing to say about muttonbirding, as he arrived after the season, but he had several restless nights on Vansittart Island due to the smell of his muttonbird feather mattress and the "incessant invasion of fleas" from it. In 1862, Archdeacon Reibey found the Islanders simple and primitive, free from the vices of more civilised life (*Tasm. Parl. Pap.* 17. 1862). Sixty-five people attended one of his church services on Chappell Island. Ten years later, on Chappell Island, Brownrigg held a service in the third week of February for 30 people who had begun to gather for the muttonbird season. The schoolmaster had even erected his tent on the island to continue teaching the children (Murray-Smith 1979).

Brownrigg could never reconcile himself to muttonbirding. He was revolted by the activities and the smell. On his first visit in 1872 he described Chappell Island as very bleak and barren looking, and infested with snakes (Murray-Smith 1979). He

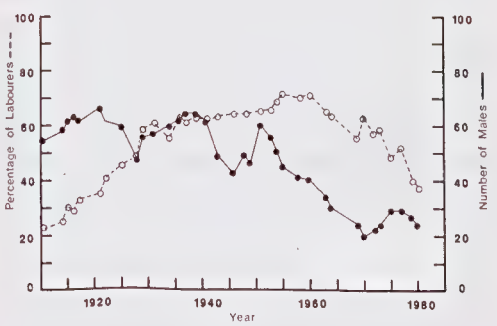

FIG. 4 — Variation in number of males, 20 years and over on Cape Barren Island, and percentage of these who occupation was listed as labourer. (Source: Commonwealth Electoral rolls.)

was struck by the crudeness of the huts which he described (Murray-Smith 1979) as:

> "... odd looking structures; they seldom exceeded four feet in height at the walls, and about six feet at the ridge. The sides and roof are made up of light sticks, and covered in with long coarse grass. An opening at the side forms the door, and a few stones built up at one end serves for the fireplace. Grass is then strewed upon the earthen floor, and the habitation is considered to be complete. These huts are tenanted only during the 'season', being manifestly unsuited for the colder portions of the year."

In 1872 the season here consisted of oiling, fatting and salting. Oiling was catching fledglings that were not large enough for processing, obtaining the oil and using the carcase for fatting. On average

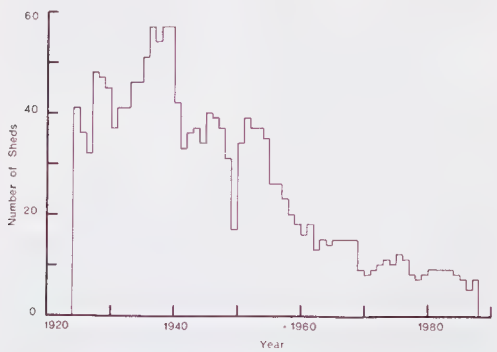

FIG. 5 — Seasonal fluctuations in number of muttonbird sheds in the Furneaux Group, 1924–88.

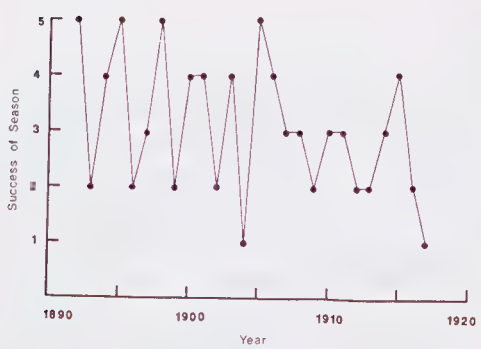

FIG. 6 — Annual muttonbird seasons from 1892-1917. Scale: 1, exceptionally poor season; 2, below average; 3, average; 4, above average; 5, exceptionally good.

100 birds produced one gallon of oil and a good season would yield about 3000 gallons of oil (Murray-Smith 1979). Fatting was trying out the skins in a pot or boiler and collecting the fat; in certain instances pressure was also used in trying out. The third stage was salting, in which birds were salted and packed in barrels. Enough feathers were gathered during the course of this season for no special attack to be made upon the birds, as was done in the early years of the industry. By 1892, oiling and fatting of young fledglings was prohibited and only the entrails of older fledglings reduced (*Launcestion Examiner* 26 April 1892). The season has remained like this up to the present day, except that fat is no longer obtained.

Chappell Island remained the main muttonbirding island for so long because of its large quantity of birds, its accessibility and its close proximity to the settlement on Cape Barren Island and other islands. It had 105 inhabitants in April 1879 (*Tasm. Parl. Pap.* 56. 1879 Bass's Straits: Report of Dr. Vines upon the fever in the islands). In 1890, Bishop Montgomery found 21 families muttonbirding on Chappell Island (Montgomery 1892). Montgomery was an energetic person with great social concern for Aboriginal Tasmanians on the islands (Hart 1963, Stephens 1985) and also showed much interest in the fauna, especially short-tailed shearwaters. He prevailed upon the Government to bring in the first laws governing the season, in which muttonbirding was only permitted between 20 March and 20 May (*Tasm. Gov. Gaz.* 15 Dec. 1891). Chappell Island probably peaked in the 1890's/1900's; nearly 200 people were engaged in muttonbirding at 20 sheds in 1890 (*Launceston Examiner* 8 May 1890) and 155 in 1908 (*Tasm. Parl. Pap.* 57. 1908 Furneaux Islands: Report upon the state of the islands by Mr. J.E.C. Lord, Commissioner of Police). In 1908 there were only 78 persons employed on Babel Island; however, by 1936 there were 24 sheds operating there and only six on Chappell Island. On other islands in 1936 there were 12 sheds on Great Dog Island, six on Little Green Island and three on Little Dog Island (fig. 5).

Little sailing boats picked up the casks of birds, oil and fat from each shed on the birding islands. They were brought into Launceston, most sold locally and some exported to the mainland or, later, as far away as Germany and New Zealand. There are very few figures for the number of birds caught in the 19th century, the only information available being subjective opinions of correspondents to the *Launceston Examiner* on what sort of season occurred. These opinions have been graded from 1 (exceptionally poor) to 5 (exceptionally good) and

depicted in figure 6; this shows that each season was different but that exceptionally good and bad seasons occurred infrequently.

Time had caught up with the Islanders during the second half of the 19th century. Alienation of the Furneaux Group by Europeans began under the *Waste Lands Acts* of 1861–70. Parts of Chappell Island were leased and stocked (Ryan 1981) and in 1887 land on Flinders Island was made available for sale following a survey of the island (*Tasm. Parl. Pap.* 62. 1887 Report on Flinders' Island, by John W. Brown Surveyor) bringing about a rapid increase in population.

In June 1863 Archdeacon Reibey found 28 men, 27 women and 48 children scattered around the islands (*Tasm. Parl. Pap.* 48, 1863). The first census for the Furneaux Group gathered on 7 February 1870 gave a population of 242 (138 males:104 females) of whom 132 were 16 years or older (table 3). Only 13 men were engaged in farming or seafaring, the remaining adults were either hunters, self-employed or, in the case of women, doing home duties. Less than half the population could read or write. In 1881 the population was 252 (137 males : 115 females). Electoral role figures available since 1910 show that the population of Cape Barren Island increased in the 1920's and then steadily declined (fig. 6). The tradition of hunting, which included muttonbirding, continued after the First World War. In the 1911 census 81 men gave their livelihood as the capture of animals and their products. In 1921, 140 were engaged in hunting but occupations changed over the years as people looked for steady income, mainly as labourers (fig. 6).

Elsewhere in Australia muttonbirding was carried on to any extent only in Victoria, where eggs and chicks were collected principally for home consumption (*Launceston Examiner* 12 April 1873, Campbell 1900). The taking of birds was prohibited there sometime during the 1920's (Lewis 1923).

Australia Post-1930

A decline in the number of muttonbird sheds in the Furneaux Group occurred in the 1930's. This decade was greatly affected by social conditions brought about by the Great Depression which forced people to leave Cape Barren Island and seek work on Flinders Island or Tasmania. Figure 6 shows a steady decline in the number of men on Cape Barren Island from about 60 in 1920 to only 20 in 1980. In the last 60 years, the annual take has declined from almost one million to about 300 000 chicks (Skira 1987). The reasons are mainly social, such as changing eating habits in Tasmania (as people have no longer grown up with a tradition of muttonbirding), increasing expenses and decreasing participation in muttonbirding by younger Aboriginal Tasmanians.

By 1961, when the population in the Furneaux Group was 1407 (table 3), shearwaters had become relatively unimportant economically although the social tradition was still strong (Skira 1987). The value of the 1985 commercial season in Tasmania was $328 000 of which $120 000 was contributed from the Furneaux Group and $208 000 from the Hunter Group.

Hand-in-hand with commercial muttonbirding was the taking of birds purely for home consumption. The taking by amateurs began early in the settlement of Tasmania but became widespread only when shearwaters first began to breed near population centres, approximately 60 years ago. Access to colonies by vehicles and boats became easy, and muttonbirding reached its peak in 1977 when almost 8000 licences were sold. In recent years, the season has only been permitted on the west coast and Bass Strait islands. The daily bag quota is 10 birds on the west coast and 25 birds in Bass Strait.

New Zealand

Thirty-two petrel and seven albatross species breed in the New Zealand region (Readers Digest 1985). A large number of these were once exploited by Maoris and the Morioris (Scarlett 1979, Davidson 1984) and for the most part taken from areas where they breed at present. In fact, the inhabitants found almost every bird edible and even ate specimens (e.g. short-tailed shearwater) washed up on beaches. Today, only the sooty shearwater *Puffinus griseus* and grey-faced petrel *Pterodroma macroptera* are allowed to be taken by Maoris and their descendants, and only the former may be sold commercially. Occasionally the mottled petrel *Pterodroma inexpectata* is taken in association with these (Robertson & Bell 1984).

The short-tailed shearwater has been recovered from two middens in the Chatham Islands (one bird each — Sutton 1979), one at Tiwai Point, South Island (two birds — Sutton & Marshall 1980) and from middens at Tom Bowling Bay, North Island, and at Marfell Beach, South Island (Scarlett 1979); they were all probably gathered from the beach.

Northern Hemisphere

The two principal ethnic groups of the Arctic are the Aleuts and Inuits (Eskimos). The Aleuts did not eat short-tailed shearwaters or did so sparingly. Murie (1959), who spent much time with this group does not mention their harvesting of this species.

Information on use of short-tailed shearwaters by Inuits is conflicting. Portenko (1972) states that despite shearwaters being present in large numbers they are not eaten by local people, giving lack of meat and fat on the birds as the reason. However, short-tailed shearwaters have been found in prehistoric Inuit sites (Friedmann 1934a, b, 1941) — one coracoid each from St Lawrence Island (2000 years old) and Amaknak Island (probably 1000 years old) and two humeri from Cape Prince of Wales (1000 years old). Friedmann (1941) concludes, because of the scarcity of remains, that the short-tailed shearwater was rarely eaten by the Inuits of Cape Prince of Wales region. Murie (1959) mentions that the Inuit inhabitants of St Lawrence Island have certain taboos in connection with eating the bird. However, Robert Day (pers. comm.) writes that Dr Francis Fay, who until recently lived with the Inuits for many years on St Lawrence Island, stated that they do hunt short-tailed shearwaters and find them to be "very fat and very tasty" and that Murie probably obtained secondhand his information that they were taboo.

There is no evidence that short-tailed shearwaters, frequently washed up on beaches along the east coast of Japan, were used for food (Oka & Maruyama 1986), but until recently the Japanese harvested small numbers of the native streaked shearwater *Calonectris leucomelas* which breeds in large numbers, mainly on islands off Honshu.

CONCLUSION

Short-tailed shearwaters have been exploited by humans for thousands of years throughout their migratory range. In Tasmania, archaeological evidence indicates that Aboriginals used them as incidental food to other vertebrates such as seals, wallabies, wombats and wildfowl.

The arrival of Europeans in Tasmania changed muttonbirding from a dietary activity to one on which a bush economy was maintained for many years. The sealers who settled on the Bass Strait islands hunted game, farmed the land and collected shearwaters for their livelihood. The early industry was unaware of the importance of conservation of the birds and adult birds, eggs and chicks were taken from October to May. It was only about the 1860's that muttonbirding became confined to chicks.

Until the 1920's muttonbirding was the main economic activity of Bass Strait islanders. Annual catches of up to one million chicks were reported and over 200 people used to gather on Babel Island alone. The tradition of muttonbirding changed with the advent of the Second World War, when social influences and modern life styles brought altered attitudes. Today, commercial muttonbirding is regarded as a declining industry.

Alongside commercial muttonbirding was the taking of birds for home consumption only. Amateur muttonbirding led eventually to bag limits and other restrictions as hunting pressure became excessive, to the point where, since 1987, it has been restricted to the west coast and Bass Strait Island, and to only two weeks. Over-exploitation, physical damage to colonies and changing social attitudes to muttonbirding or "shearwater slaughter" are some of the causal factors.

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